PRACTICAL RULES

FOR THE

PROPORTIONS

OF

MODERN ENGINES AND BOILERS

FOR

LAND AND MARINE PURPOSES.

BY

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BURGH'S PRACTICAL RULES

FOR

MODERN ENGINES AND BOILERS.

HIGH PRESSURE ENGINE.

THIS class of engine varies in arrangement and design, viz.: vertical, direct, inclined, inverted direct, oscillating, and horizontal; the last-mentioned being the most practical, is therefore universally adopted. To enumerate the different arrangements of this class of engine would be absurd, the author's intention being to give an example of the best and most practical he has met with; thus the cylinder is secured to a cast iron bed plate, which has provisions cast on it to receive all the connections, etc., the slide valve works against the front side of the cylinder, the piston rod being guided by a T shaped guide which works underneath the rod, in a channel, the top part of which is separate, being secured by bolts or studs, and nuts, the guide block receives the end of the connecting rod, which is attached to the crank pin in the usual manner; the crank and

shaft are in one forging, the latter works in brasses, secured in a projection, cast either right or left on the bed plate, the eccentric keyed on the crank shaft is secured beyond the bearing, the throw being sufficient to work the feed pump and slide valve, the former being secured on the opposite side to that of the main bearing; the weigh shaft of the levers works in a boss, cast underneath the guide channel, the levers are connected to the slide valve rod and feed pump with disengaging sockets, so as to be disconnected instantaneously. The ball governor is supported in a standard, secured on the side of the cylinder opposite the slide valve casing, the governor deriving its motion from mitre gearing, driven by a belt passing round the crank shaft; the steam valve is regulated by a lever from the governor. By this arrangement, correctness, durability, simplicity, and access to all the details, is effected, being also economical both in price and working.

Designing.

In designing an engine of any kind, symmetry and economy should be observed, also that all the working parts should be accessible, without disarranging any detail; there should be sufficient strength in the various parts subject to excessive strains, such as the main frame, shaft, crank, connecting rod, bolts, nuts, etc.; lightness should be

strictly adhered to, compatible with strength; in the case of flanges, ribs should be introduced between each bolt or stud to support the flange in the case of any undue strain. When any holes are cast, the centre part should be cored larger than the ends, so as to allow for fitting or boring; provisions for fitting should in every case project from the body of the casting, so as to allow for planing or chipping.

RULES.

POWER.

The term nominal horse power being conventional, each maker has his own data for the proportion, hence the variation in engines of the same nominal power. The author has collected practical evidence of the best proportion together with his own experience. The rules for the steam engine will now engross the attention of the reader.

Horse Power (Nominal.)

The area of the cylinder = 7 to 9 square inches per nominal HP. The stroke in most cases = twice the diameter of the cylinder.

RULE.

Having determined the size of the engine, × the HP by the number of square inches agreed

on, the product = the area of the cylinder, from which obtain the diameter, the whole numbers of which, × by 2 = the stroke, decreasing slightly in large engines. It is practically essential that even dimensions be adhered to, remembering to increase rather than decrease the product when areas of circles are in question.

EXAMPLES.

4 HP = 4 × 9 = 36 = $6\frac{1}{8}$ diameter; stroke 12 inches.

6 HP = 6 × 9 = 54 = $8\frac{5}{16}$ diameter; stroke 16 inches.

8 HP = 8 × 8.75 = 70 = $9\frac{1}{2}$ diameter; stroke 18 inches.

10 HP = 10 × 8.5 = 85. = $10\frac{7}{16}$ diameter; stroke 21 inches.

12 HP = 12 × 8.25 = 99 = $11\frac{1}{4}$ diameter; stroke 22 inches.

15 HP = 15 × 8 = 120 = $12\frac{3}{8}$ diameter; stroke 24 inches.

20 HP = 20 × 8 = 160 = $14\frac{5}{16}$ diameter; stroke 28 inches.

25 HP = 25 × 7.8 = 195 = $15\frac{1}{8}$ diameter; stroke 30 inches.

30 HP = 30 × 7.78 = 233 = $17\frac{1}{4}$ diameter; stroke 34 inches.

35 HP = 35 × 7.75 = 272 = $18\frac{5}{8}$ diameter: stroke 36 inches.

40 HP = 40 × 7.5 = 300 = $19\frac{9}{16}$ diameter; stroke 40 inches.

50 HP = 50 × 7 = 350 = $21\frac{1}{8}$ diameter; stroke 42 inches

Power (Actual).

The first consideration relative to the actual power of an engine, is to ascertain the force exerted against the piston, also its speed in a given time. It is evident that what is gained in time is lost in power, and *vice versâ*, presuming the same total power to be exerted throughout. Thus, 10 tons lifted in 6 minutes @ 10 lifts = 100 tons per hour, or 5 tons lifted in 3 minutes @ 20 lifts = 100 tons per hour. The actual power of the steam engine is due to the force exerted by the piston, produced from the pressure of the steam; it is deemed universally decisive that 33,000 lbs. is the constant number for one-horse-power raised one foot high per minute, hence the following

RULE.

Multiply the area of the piston by the pressure per square inch, the product by the speed of the piston per minute, equals the force in lbs., this last, divided by 33,000, equals the actual horse power, including the friction. The following examples will enable the reader to understand the principle; 30 lbs. pressure per square inch, and speed of piston 200 feet per minute being adopted:

Noml.		Actl.
4 HP	$=\dfrac{36\times30\times200}{33000}=$	6.5 HP
6 HP	$=\dfrac{45\times30\times200}{33000}=$	8 HP
8 HP	$=\dfrac{70\times30\times200}{33000}=$	12.7 HP
10 HP	$=\dfrac{85\times30\times200}{33000}=$	15.4 HP
12 HP	$=\dfrac{99\times30\times200}{33000}=$	18 HP
15 HP	$=\dfrac{120\times30\times200}{33000}=$	21.8 HP
20 HP	$=\dfrac{160\times30\times200}{33000}=$	29 HP
25 HP	$=\dfrac{195\times30\times200}{33000}=$	35.45 HP
30 HP	$=\dfrac{233\times30\times200}{33000}=$	42.3 HP
35 HP	$=\dfrac{272\times30\times200}{33000}=$	49 HP
40 HP	$=\dfrac{300\times30\times200}{33000}=$	54.54 HP
50 HP	$=\dfrac{350\times30\times200}{33000}=$	63.63 HP

CYLINDER.

Area = HP nominal × 9 to 7.

Diameter = $\sqrt{\text{area}} \times 1.1283$.

Depth of piston $= \dfrac{\text{diameter}}{4}$

Stroke = diameter × 2.

Clearance for piston at each end of the stroke = $\frac{\text{diameter}}{30}$

Allowance for re-boring, or increased diameter to receive cover = $\frac{1}{8}$ to $\frac{3}{16}$ of an inch + the radius of the diameter of cylinder.

Internal length of cylinder = stroke + piston + clearance at each end.

Piston rod diameter = $\frac{\text{diameter of cylinder}}{6 \text{ to } 7}$

Thickness of body of cylinder. This cannot be deduced from a fixed rule which would be practical in all cases. For example, a cylinder of an engine 6 inches diameter should equal at least $\frac{5}{8}$ of an inch in thickness, whereas, one 24 inches in diameter would be $1\frac{1}{2}$ inches in thickness; the former equals $\frac{1}{96}$ of the diameter, while the latter equals $\frac{1}{16}$ of the diameter, thus showing practice is the best guide. The following, compiled by the author, will dispense with calculations and confusion of opinion:

HP nominal.		Diameter.		Thickness of Body.
4	...	$6\frac{13}{16}$	...	$\frac{5}{8}$
6	...	$8\frac{5}{16}$	...	$\frac{11}{16}$
8	...	$9\frac{1}{2}$	...	$\frac{3}{4}$
10	...	$10\frac{7}{16}$	...	$\frac{13}{16}$
12	...	$11\frac{1}{4}$	...	$\frac{7}{8}$
15	...	$12\frac{3}{8}$	...	$\frac{15}{16}$
20	...	$14\frac{5}{16}$	...	1

HP nominal.		Diameter.		Thickness of Body.
25	...	$15\frac{13}{16}$	...	$1\frac{1}{16}$
30	...	$17\frac{1}{4}$	...	$1\frac{1}{8}$
35	...	$18\frac{5}{8}$	...	$1\frac{3}{16}$
40	...	$19\frac{9}{16}$	...	$1\frac{1}{4}$
50	...	$21\frac{1}{8}$	...	$1\frac{3}{8}$

The above includes the allowance for re-boring, but, when the speed of the piston is intended to exceed 300 feet per minute, $\frac{1}{16}$ of an inch should be added per 100 feet to the thickness given.

Thickness of raised portions $= \frac{\text{thickness of body}}{5}$.

Length of raised portions = thickness of body × 2.

Thickness of metal of steam passages = thickness of body × .8 to .6.

Thickness of back end cover = thickness of body × .8 to .6.

Depth of fitting part of cover = thickness of body.

Thickness of flanges = thickness of body × 1. to .8.

Thickness of ribs = that of the body × .5 to .4.

Internal diameter of recess for nut of piston rod = diameter of screw part × 2.

Diameter of studs and bolts for securing cover = thickness of body below one inch.

Pitch circle of bolts or studs = diameter of fitting part of cover + twice thickness of body + diameter of stud or bolt.

Thickness of metal beyond stud or bolt = bolt's diameter × .75.

Diameter of nut bosses = size of nut across the angles × 1.1.

Thickness of bosses = $\frac{1}{8}$ of an inch.

Thickness of front end of cylinder = thickness of body × .8 to .6.

Thickness of ribs (4) = thickness of front end × .8 to .6.

Position of supporting brackets (perpendicular) = radius of cover + $\frac{1}{4}$ to $\frac{3}{4}$ of an inch.

Thickness of sole = thickness of body × 1 to 1.2.

Thickness of ribs = that of sole × .8 to .6.

Space between ribs = size of nut of securing bolts across the angles × 3. to 2.

Diameter of securing bolts (4) = diameter of piston rod × .7 to .6.

Transverse distance of securing bolts = diameter of cylinder.

Stuffing Box and Gland.

Piston rod stuffing box diameter = piston rod's diameter × 1.75.

Depth = diameter of rod × 1.5.

Thickness of the metal of the bush = $\frac{\text{dia. of rod}}{6 \text{ to } 8}$.

Gland depth = depth of stuffing box × .8 to .87.

Thickness of metal of stuffing box = thickness of the gland.

Diameter of gland studs = piston rod × .3 to 25.

The metal around the gland stud = diameter of stud × .75.

Depth of oil cup $= \dfrac{\text{piston rod diameter}}{2}$

Thickness of gland flange = diameter of studs.

Steam Port (Supply.)

Area $= \dfrac{\text{area of cylinder}}{15 \text{ to } 20}$ = about ½ square inch.
per H P nominal.

Length = diameter of cylinder × .6 to .7.

Width $= \dfrac{\text{area}}{\text{length}}$

Width and length of steam passage = ⅛ of an inch + that of port.

Exhaust port area = supply port × 1.5.

Outside lap of slide valve $= \dfrac{\text{width of supply port}}{2 \text{ to } 3}$

Inside lap $= \dfrac{\text{outside lap}}{5 \text{ to } 6}$

Side lap of slide valve = width of supply port × .6 to .5.

Width of bar = outside lap + inside lap + width of port supply.

Position of valve facing = thickness of body × 1.3 to 1.4 + width of steam passage + radius of external diameter of cylinder.

Stroke of slide valve = width of port supply + outside lap × 2.

Diameter of slide valve rod = piston rod × .6 to .5.

Stuffing box diameter = diameter of valve rod × 1.8.

Depth = diameter of valve rod × 1.6.

Thickness of bush = $\frac{1}{8}$ to $\frac{3}{16}$ of an inch.

Depth of gland = depth of stuffing box × .75.

Thickness of metal of stuffing box = thickness of gland.

Diameter of studs (2) = diameter of valve rod × .4 to .5.

$$\text{Clearance for slide} = \frac{\text{stroke}}{7.\text{ to }9.}$$

Depth of slide valve internally = width of exhaust port.

Thickness of body of slide = $\frac{3}{8}$ to $\frac{5}{8}$ of an inch; if more than 9 inches wide, a rib should be cast centrally.

Thickness of flange of slide valve = $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

Position of rod. from face = diameter of rod + thickness of flange.

SLIDE CASING.

Thickness of casing = thickness of the metal of steam passage.

Thickness of flange = that of the body × 1.125.

Width of flange = studs' diameter × 2.1 + thickness of body.

Thickness of cover = thickness of body × .8 to .7.

Diameter of studs = thickness of cover.

Thickness of ribs = thickness of cover × .6 to .5.

Piston.

Thickness of body = thickness of cylinder × .7 to .5.

Thickness of ribs = thickness of body × .7 to .6.

Superficial area between ribs = $\frac{\text{area of piston}}{8 \text{ to } 12}$

Diameter of packing ring studs = thickness of metal of body.

The mode of rendering the piston steam-tight around the periphery, is by a spring of cast iron in the form of a ring, thicker at one side than the other, the lesser being divided at an angle of 45°. To prevent the steam from rushing through this opening, a piece of gun metal, termed a tongue, is inserted centrally in the depth of the ring, on one side of the division, the opposite side being plain, but carefully fitted, so as to allow the expansion and contraction of the ring without the steam passing through; the spring is rendered permanently effective by a packing behind it, either of small springs, or a gasket of a parallelogram in section; the ring studs should screw into gun metal blanks, inserted centrally of the depth of the piston.

Thickness of stud blocks = 1.12 to 1.7 × by the stud's diameter.

Side of square of stud block = diameter of stud × 1.8 to 1.7.

Thickness of spring at the thickest part = $\frac{1}{2}$ inch per foot in diameter.

Thickness of ring at divided part = thickest part × .7 to .6.

PISTON ROD.

The modes of connecting the piston rod to its cross head are various; usually, by inserting the end in the hollow end of a single or double eye, secured by a cotter; a better mode is to make the end of the rod of a **T** shape, secured to the guide block by bolts.

Taper of rod in piston = $\frac{3}{8}$ of an inch per foot.
Depth of nut = diameter of rod × .8 to .7.
Area of securing bolts = area of rod.
Thickness of **T** end = diameter of bolts.
Width of **T** end = bolts' diameter × 2.

CROSS HEAD OR CONNECTING PIN.

Diameter = diameter of piston rod × 1.4 to 1.3.

GUIDE BLOCK.

This guide block is of the usual kind, adapted for high speeds; the cross head or connecting pin works in the upper part. In some cases the block is in halves; but the better mode is to make the back part solid, and the front part loose between the securing bolts, secured by a cap in front.

Bottom area of guide $= \dfrac{\text{area of cylinder}}{\text{ratio of length of connecting rod to stroke}}$

Length = stroke of engine × .45 to .4.

Width $= \dfrac{\text{area}}{\text{length}}$

Thickness = width × .3 to .25.

Thickness of shoe $= \dfrac{\text{thickness of guide}}{2}$

Taper of adjusting part of shoe = $\frac{1}{4}$ inch per foot.

Diameter of adjusting stud = thickness of shoe.

Length of bearing of connecting pin = diameter × 1.5.

Thickness of metal around bearing $= \dfrac{\text{diameter}}{4 \text{ to } 6}$

Thickness of back part = bearing's diameter × .4.

Thickness at front part = that of back × .5.

Depth of recess for soft metal = $\frac{1}{8}$ to $\frac{3}{16}$ of an inch.

Thickness of cap = diameter of securing bolt.

Width of cap = thickness × 2.

Connecting Rod.

Length = stroke of engine × 2 as a minimum.

Length of fork from centre of eye = diameter of connecting pin × 2.5.

Width of each fork = diameter of connecting pin.

Thickness of each fork = width × .5.

Thickness of metal around pin = diameter × .4 to .36.

Width of eye = thickness of fork × 1.25.

Diameter of connecting rod (fork end) = piston rod's diameter × 1.125.

Diameter of connecting rod at crank end = diameter of piston rod × 1.25.

Diameter of connecting rod at centre = $\frac{1}{16}$ of an inch per foot in length + diameter at crank end.

The form of heads for the connecting rod is various; the most practical for adjustment, and renewal of brasses, is the marine kind, viz., T head with flat brasses, and cap, or solid head in halves, with hexagonal or round brasses.

Diameter of crank pin = diameter of piston rod × 1.5.

Length of bearing = diameter of pin × 1.5.

Thickness of the brasses at the ends =

$$\frac{\text{diameter of pin}}{4 \text{ to } 6}$$

Thickness of the sides = thickness of ends × .5.

Diameter of adjusting bolts = diameter of securing bolts for guide block.

Thickness of metal between brass and side of bolt $= \dfrac{\text{diameter of bolt}}{6. \text{ to } 8.}$

Thickness of brass at extremities of bearing =

$$\frac{\text{diameter of bearing}}{5. \text{ to } 7.}$$

Thickness of the flanges of brasses = thickness of the sides.

Diameter of flanges = extreme distance across the angles + thickness of one side of brass.

Thickness of the head of the connecting rod beyond brasses = crank pin's diameter × .5.

When caps are used and flat brasses, proportions of brasses and bolts will be as for a solid head.

Thickness of flat brass between bearing and side of bolt = $\frac{1}{8}$ to $\frac{3}{16}$ of an inch.

Thickness of cap = diameter of adjusting bolt.

Width of the head or cap = diameter of adjusting bolt × 2.

Eccentric.

The stroke is obtained from the length of the lever and stroke of slide valve.

$$\text{Thickness of boss} = \frac{\text{diameter of shaft}}{4 \text{ to } 6}$$

Thickness of ribs (3) = thickness of boss × .5 to .4.

Taper of ribs = $\frac{1}{2}$ inch per foot in length.

Thickness of rim = thickness of boss × .8 to .7.

Depth of recess $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Thickness of sides of recess = depth of recess.

When the eccentric works the slide valve only. The throw = half stroke of slide valve.

$$\text{Thickness of boss} = \frac{\text{diameter of shaft}}{5 \text{ to } 7}$$

The remaining proportions are the same as above.

ECCENTRIC ROD BAND AND BOLTS.

Diameter of rod T end = diameter of slide valve rod × 1.5.

Length = length of connecting rod.

Diameter of rod at lever end = diameter at T end × .9 to .8.

Diameter of rod at centre = $\frac{1}{12}$ of an inch per foot in length + diameter at T end.

Area of each bolt and stud = area of valve rod.

Thickness of T end = diameter of bolt.

Thickness of band = diameter of bolt × .5 to .4.

Thickness of flanges of band = thickness of band × 1.5.

Width of band = nut across angles × 1.1.

When the eccentric works the slide valve only.

Diameter at T end = diameter of valve rod × 1.25.

Diameter at valve rod end = diameter of valve rod.

Area of bolts and studs = area of valve rod × .8.

Diameter of weight shaft for levers of feed pump and slide valve = diameter of valve rod × 2.

Diameter of weight shaft for working slide valve only = diameter of slide valve rod × 1.3.

MAIN FRAMING.

The main framing of an engine is that part which is susceptible to every strain to which the engine is liable. Many makers of engines cast this frame in two or more pieces; such a practice

is bad, being productive of disarrangement, and undue strain to the working and rigid parts, as in the case of the connecting bolts becoming loose, etc.—a too often occurrence in engines of high speed. The author has endeavored to produce a good example, of what a frame or bed plate of an engine should be in cast iron, with a proper distribution of material. The following rules will enable the reader to judge as to the veracity of his statement:

Thickness of metal = thickness of cylinder × .8 to .7.

Width of each side of frame $= \dfrac{\text{diam. of cylinder}}{2}$

Depth of frame = width × .5.

Distance between centre of sides = diameter of cylinder.

Height of facing projections = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Diameter of bosses of securing bolts = bolts' diameter × 2.

Length of guide channel =

$$\frac{\text{length of guide block}}{4} + \text{stroke of engine.}$$

Thickness of flange part of guide channel = thickness of guide × 1 to .875.

Diameter of flange studs = thickness of flange × 1. to .75.

Pitch of bolts = diameter × 8.

Thickness of metal on each side of bolt = bolt's diameter × .75.

Thickness of metal under guide = thickness of guide.

Diameter of holding down bolts of frame (6) = diameter of securing bolts for cylinder.

Diameter of lever weigh shaft boss = diameter of shaft × 2.

Thickness of bush = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Diameter of crank shaft's bearing = diameter of piston rod × 2. as a minimum.

Length of bearing = diameter × 1.5.

Position of centre of bearing from centre line of framing = diameter of bearing × 2. as a minimum.

$$\text{Thickness of brasses of bearing} = \frac{\text{diam. of bearing}}{6 \text{ to } 7}$$

Area of each adjusting bolt = area of piston rod × .7 to .6.

Thickness of cap = diameter of bearing × .6 to .5.

Thickness of metal between brass and side of

$$\text{bolt} = \frac{\text{bolt's diameter}}{4}$$

Thickness of metal above side of adjusting bolts = diameter of bolt × .5 to .4.

Thickness of clip = thickness of metal above side of adjusting bolts × .5.

Crank and Shafts.

Area of the crank = area of shaft's bearing.

Thickness of crank = diameter of bearing × .8 to .7.

Diameter of shaft beyond bearing = diameter of bearing $\times$ 1.2 to 1.12.

Diameter of collar of crank pin = diameter of pin $\times$ 1.125 to 1.2.

Fly Wheel.

Weight of rim in cwts. = nominal HP $\times$ 3. to 2.

Diameter to centre of rim = stroke of engine $\times$ 4. to 3.

Cubical contents of rim $= \dfrac{\text{weights in lbs.}}{.263}$

Sectional area =

$$\frac{\text{cubical contents}}{\text{circumference of rim at centre line in inches}}$$

Depth of rim $= \dfrac{\text{diameter at centre of rim}}{8 \text{ to } 10}$

Width of rim $= \dfrac{\text{sectional area}}{\text{depth}}$

Diameter of boss = diameter of shaft by 2.5 to 2.

Length of boss = diameter of shaft $\times$ 2.

Number of arms 6.

Sectional area of arm $= \dfrac{\text{area of rim}}{\text{number of arms}}$

Width of arm at rim $= \dfrac{\text{depth of rim}}{2}$

Taper of arm = $\frac{1}{2}$ inch per foot.

Area of connecting bar of rim $= \dfrac{\text{area of rim}}{3 \text{ to } 4}$.

Width of connecting bar $= \frac{\text{depth of rim}}{3 \text{ to } 4}$

Depth of key = width of connecting bar.

Width of key = depth × .3 to .2.

Width of boss rings $= \frac{\text{length of boss}}{4 \text{ to } 5}$

Thickness of boss rings = width × .6 to .5.

Feed Pump.

The rules given for this pump are generally both abstruse and obtuse, thus confounding the uninitiated with perplexing calculations having no reference to the cause of requirement. It must be clearly understood that in no case whatever can the proportions of the feed pump be obtained from the diameter of the cylinder, length of stroke of the engine, and such-like insane ideas. The proper mode of ascertaining the proportions of any portion of mechanism, is to deduce it from the prime mover; therefore, in the case of the feed pump, common sense implies that the pressure of the steam, and the cubic contents of the cylinder, must imperatively be the origin of the requirements to keep a proper supply of water in the boiler. The following simple rules will be found practically correct:

Cubic contents of feed pump in inches (see Table below) = contents of cylinder + cubic contents

of one steam passage in feet × 4 times the number of cubic inches of water to produce a cubic foot of steam.

Pressure of Steam.				Cubic inches of water to produce 1 cubic foot of steam
10	...	...	...	1.7
15	...	...	...	2.0
20	...	...	...	2.3
25	...	...	...	2.6
30	...	...	...	2.9
35	...	...	...	3.2
40	...	...	...	3.5
45	...	...	...	3.8
50	...	...	...	4.0
60	...	...	...	4.6
70	...	...	...	5.1
80	...	...	...	5.65
90	...	...	...	6.2
100	...	...	...	6.68

Stroke of pump is obtained from the length of lever and stroke of slide valve, when the same lever is used to work the slide valve.

Area of valve = area of plunger × .6 to .7. Valves are generally of India-rubber.

Thickness of body of plunger = $\frac{3}{32}$ to $\frac{1}{16}$ of an inch per inch in diameter, per 20 lbs. per square inch of pressure of steam in boiler.

Thickness of end = thickness of body × 2 to 1.5.

Area of plunger pin = area of eccentric rod (lever end) × .8.

Diameter of stuffing box = diameter of plunger 1.6 × to 1.4.

Depth of stuffing box = diameter of stuffing box × .5 to .4.

Depth of gland = depth of stuffing box × .7 to .8.

Diameter of gland studs (2) = diameter of pump × .3 to .2. The studs should never exceed 1¼ inch diameter.

Thickness of flange = diameter of studs.

Thickness of body of pump (gun metal) = thickness of plunger × 1.5 to 1.3.

Thickness of body of pump (cast iron) = thickness of plunger × 1.8 to 1.6.

Feed Pump Relief Valve.

This valve is connected to the pump pipe between the discharge valve and the boiler, so that in the case of any obstruction being in the pipe, or the feed cock closed, the relief valve will act, and prevent any disarrangement or rupture of the engine pipe, etc. The most practical position for this valve is directly over the discharge valve of the pump.

Diameter of valve = diameter of feed pipe.

Diameter of spring = diameter of feed pipe.

The sectional area of spring is a difficult result to be obtained, as the temper of the steel, the number of coils, and space between, will materially alter the pressure or action of the spring. The following will be an approximation, enabling exactitude to be obtained by the adjusting screw:

Number of coils = 6 to 8.

Diameter of section of coil of spring equals .25 of an inch per 2 inches in diameter, having an increase slightly in springs below 2 inches in diameter.

Space between coils = thickness of coil × 2. to 1.5.

$$\text{Diameter of valve spindle} = \frac{\text{diameter of valve}}{4 \text{ to } 6}$$

$$\text{Thickness of valve} = \frac{\text{diameter of spindle}}{2}$$

GOVERNOR.

The proper mode of ascertaining the actual length of the levers, pendulum, and spindle of the governor, is to determine the length or height of the plane line, and set out the centre lines of the pendulum at an angle of 60°, as their position at the proper speed; the angle should never exceed 45° when at the greatest velocity, but this angle will rarely, if ever, be obtained, if the governor be properly proportioned.

The centre of suspension should imperatively be on the centre of rotation; if below it, the cone becomes a frustrum or part of a cone, thus destroying the principle from which the ball governor is deduced.

Height of plane line from suspension = stroke of engine × .5 to .4.

Number of revolutions of governor =

$$\frac{187.5}{\sqrt{\text{height of plane line from point of suspension.}}}$$

Diameter of mitre gear = height of plane line × .4 to .3.

Pitch of teeth = $\frac{1}{8}$ to $\frac{3}{32}$ of an inch per inch of diameter.

Diameter of weigh shaft = pitch × 2.

Number of revolutions of engine =

$$\frac{\text{speed in feet}}{\text{stroke in feet} \times 2}$$

Diameter of spindle = $\frac{1}{2}$ to $\frac{5}{8}$ of an inch for 12 inches in length.

Position of connecting lever on pendulum = $\frac{2}{3}$ of the distance from point of suspension to the ball.

Diameter of connecting levers = diameter of pendulum × 1 to .8.

Diameter of pendulum = diameter of spindle × .6 to .5.

Diameter of pins = diameter of connecting lever.

Thickness of lever slide = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Thickness of metal of top = diameter of spindle ×·.3 to .2.

Thickness of metal of governor bracket = $\frac{1}{2}$ inch per foot in height.

Diameter of spindle and rods for governor valve = diameter of connecting levers × .7 to .6.

Diameter of balls (cast iron) = height of plane line × .5 to .4.

BEAM ENGINE (CONDENSING).

To James Watt do we owe the beautiful arrangement and combination of levers (used to produce a perpendicular line), designated the "parallel motion." This motion is universally adopted for the beam engine, although, since its introduction, guides and trunks have been used to obtain the perpendicular motion of the piston rod; practically correct as this is, but in cases where design and symmetry be observed, James Watt's parallel motion reigns supreme. The valves for the admittance and exit of the steam in and from the cylinder are various; slide valves are only used in small engines, say up to 20 HP. Cornwall, the land of beam engines, adopts the equilibrium or double beat valve, so shaped that the pressure of the steam becomes neutral in relation to the action of the valves. When slide valves are used, the common eccentric is the means adopted for working them; whereas when double beats are used, cams, levers, etc., produce the motion; the author has had the opportunity of observing practically the principle for working this valve, and has no hesitation in stating that the cam produces the best effect, on account of the irregular motion it produces, due, of course, to its particular shape. When cams are used, they are generally keyed on a shaft in front of the cylinder, which shaft is worked by mitre gear; the speed in revolutions being, of course, equal to the crank shaft; the double beat valves are side

by side in a cast iron casing, designated the nozzles, which are secured to flanges top and bottom of the cylinder; each nozzle contains a supply and exhaust valve; the primitive mode was to have four valves in one top nozzle, with pipes leading to the bottom of the cylinder. The action of the steam is always more sudden when the valves are close to their work. In single acting engines, the steam from the top nozzle is allowed to descend and do duty in the bottom nozzle, thence to the condenser, which in most cases is in front of the foundation of the cylinder. The air pump exhausts the condenser in the usual manner, either by India-rubber discs or square valves. In many cases pumping beam engines have no fly wheel, but latterly they have been introduced, and the author wonders why not before, as their introduction tends to assist and equalize the motion of the engine.

POWER.

HP.		
10 to 20	= 30 to 22	square inches per HP.
20 " 30	= 22 " 21	"
30 " 50	= 21 " 20	"
50 " 100	= 20 " 19	"
100 " 150	= 19 " 17	"

Stroke = diameter of cylinder × 2.25 to 2.

Area for port supply (for slide valve) =

$$\frac{\text{area of cylinder}}{19 \text{ to } 22}$$

Area of exhaust port = area of supply port × 1.5.

Area of port when equilibrium valves are used = area of exhaust as for the slide valve.

Length of port = diameter of cylinder × .6 to .7

Width of port $= \dfrac{\text{area}}{\text{length}}$

Diameter of piston rod $= \dfrac{\text{diameter of cylinder}}{10}$

Diameter of stuffing box = diameter of rod × 2 to 1.75.

Depth of stuffing box = diameter of rod × 4.

Depth of gland = diameter of piston rod × 2. A perforated tube of brass is inserted centrally in the depth of the stuffing box, into which steam is admitted by a pipe leading from the nozzles; by this means the stuffing box is kept air tight in relation to the cylinder.

Diameter of gland bolts 3 to 4 = diameter of piston rod × .4 to .3.

Thickness of body of cylinder allowing for re-boring =

10	inches diameter	$\frac{3}{4}$	of an inch
20	"	$\frac{7}{8}$	"
30	"	1	"
40	"	$1\frac{1}{4}$	"
50	"	$1\frac{5}{16}$	"
60	"	$1\frac{3}{8}$	"
70	"	$1\frac{1}{2}$	"

Thickness of cover = thickness of cylinder × .8 to .7.

Diameter of studs = thickness of cover × 1.25.
Thickness of ribs = thickness of cover × .8 to .7.
Diameter of bolts for securing cylinder = diameter of piston rod × .5.
No. of securing bolts = 4 to 6.
Thickness of flanges = thickness of body.
Thickness of slide or equilibrium valve, casing, or nozzles = thickness of cylinder × .8 to .7.
Thickness of flanges of nozzle = thickness of body part of casing.
Diameter of securing studs of casing = thickness of flange.
Area of valve's supply (equilibrium) =

$$\frac{\text{area of cylinder}}{19 \text{ to } 22}$$

Area of exhaust valve = area of supply valve × 1.5.

$$\text{Area in centre of valve} = \frac{\text{area of valve}}{2}$$

Angle of mitre = 45°
Width of mitred part of valve seat =

$$\frac{\text{diameter of valve}}{12 \text{ to } 15}$$

Depth of valve between seats = width of port.
Thickness of body of valve = $\frac{1}{8}$ to $\frac{3}{8}$ of an inch.
Diameter of studs for securing valve seats = $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

$$\text{Diameter of valve rod} = \frac{\text{diameter of valve}}{7 \text{ to } 9}$$

Stuffing box diameter = diameter of rod × 2.

Depth = diameter of rod × 2.
Depth of gland = diameter of rod × 1.5.
Diameter of studs of gland (2) = diameter of rod × .5.
Diameter of cam shaft = diameter of valve rod × 3.

Parallel Motion.

The design of this motion is still in most cases primitive, more particularly in the connection of the beam to the piston rod, flat bars being generally used, designated links, with distance pieces between the brasses adjusted by keys, cotters, and gibs, the said distance piece being often of cast iron, the design of which owes its origin to the so-called trellis, or cross-barred work adorning fronts of antique windows, or forming railings of gardens. In some cases, distance pieces are of wrought iron turned rods; when beams are constructed in two parts or sides, and bolted together by distance bolts, the connecting rod has a double end for the pin in the beams, whereas that for the piston rod cap is single; the same applies for beams with solid ends.

The radius rod weigh shaft may be allowed to vibrate in plummer blocks, instead of fixed with the radius rods vibrating on it. By the former adoption, the radius rods can be adjusted by nuts or cotters to the most minute exactitude, which is

the vital part of the parallel motion; the parallel bars or rods should also be adjusted as the radius rods.

Length of beam in feet = stroke of engine in feet × 3.5, in some cases 4.

Length of piston connecting rod, or link =

$$\frac{\text{stroke of engine}}{2}$$

Length of parallel bar = radius of beam × .48.

Length of radius rod = radius of beam — parallel bar $\frac{\text{remainder}^2}{\text{parallel bar}}$

Diameter of piston connecting rod = diameter of piston rod.

Diameter of parallel connecting rod = diameter of piston rod × .5 to .45.

Diameter of parallel bar and radius rod = diameter of piston rod × .5 to .4.

Diameter of piston rod cap (wrought iron) = diameter of rod × 1.6 to 1.5.

For the proportions of brasses, straps, gibs, and cotters, see Miscellaneous.

Diameter of radius rod and parallel bar weigh shafts = diameter of piston rod × .7 to .6.

Diameter of piston rod cap pin = diameter of piston rod × 1.2.

Diameter of beam end pin = diameter of piston rod × 1.2.

Depth of main beam at centre = $\frac{\text{length of beam}}{\text{6 to 7}}$

A universal rule is half stroke of engine.

Diameter or depth at end = depth at centre × .4 to .3, the line from centre to ends being a curve.

Thickness of beam with 2 parts or sides = one inch as minimum for beams 15 feet in length, having an increase beyond this ¼ inch per 10 feet of length.

Thickness of ribs and back of beam = thickness of body × 1.25.

Width of moulding, ribs, and web = thickness of body × 2. to 3.

Diameter of gudgeon = diameter of piston rod × 2.25 to 2.

The proportions of solid beams are as follows:

Thickness of beam = 1¼ inch as a minimum for beams 10 feet long, increasing in thickness ½ in. per 5 to 6 feet beyond the fixed dimension.

Thickness of rib and web = thickness of body in large beams; a slight increase in small beams.

Diameter of globe at ends of beam = depth at centre × .3 to .2.

Diameter of bosses for pins = pins' diameter × 2.5.

Depth = pins' diameter × 1.5.

Diameter of gudgeon boss = diameter of gudgeon × 2, having a moulding and ribs to strengthen it.

Thickness of rib = thickness of body × .5.

In all cases design and symmetry should be

observed in beams of cast iron, such as recessing the body, a moulding at the end of the ribs and web, etc.

Wrought Iron Beams.

This material for beams of engines is becoming more general in parts where life is considered worthy of care. Although the author has given rules for beams of cast iron, he does not advocate the use of that material for beams of steam engines, for the reason that cast iron beams must imperatively be weakened by uneven expansion and contraction in cooling, however much precaution may be taken. Cast iron beams are in one mass, whereas wrought iron are of separate parts, or plates, riveted or bolted together; for instance, in the bosses of the pins and gudgeon, practice determines that, in wrought iron, these should be secured to the body plate, rather than forged with, or even welded on it. The author's experience in the practicability and strength of wrought iron tends to demand rather than advise its use where safety is required and his superintendence is supreme.

Depth of beams at centre and ends may be as for cast iron, symmetry being the principal guide.

Thickness of sides or plates = $\frac{1}{2}$ inch as a minimum for a beam 15 feet long, increasing $\frac{1}{8}$ of an inch per 8 feet beyond this.

Width of angle iron = 2. to 3. inches.
Space between side plates = depth at centre × .2.

CONNECTING ROD.

This rod is generally of cast iron, ornamental in design. Makers of beam engines generally rely on this detail, as ladies do on their bonnets, viz., on the useful and ornamental conclusion, of the paraphernalia of the whole, in which both parties delight to indulge.

Length of connecting rod = stroke × 3.

Section at centre is usually a cross, or as the algebraic sign for plus or more.

Area at centre $= \dfrac{\text{area of cylinder}}{18 \text{ to } 20}$

Width of cross, 12 inches as a minimum for a rod 12 feet long, above this $= \dfrac{\text{length of rod}}{14 \text{ to } 15}$

Diameter of crank pin = diameter of piston rod × 1.4.

Length = diameter × 1.5.

Length of crank end of connecting rod, which is a parallelogram in section = throw of crank + radius of web of crank + clearance.

Sectional area of crank end of connecting rod = $\dfrac{\text{area of centre}}{3}$ as a minimum

Width of rod at crank pin end = diameter of

crank pin × .8 to .7, tapering to the cross part $\frac{1}{8}$ per foot.

The termination of the cross part of the connecting rod at each end is a circle.

Diameter of crank end = width of centre × .8 to .75.

Diameter of termination at beam end = diameter at crank end × .875.

In cases where the connecting rod is required to be forked at the beam end, that part is cast with the remainder.

Area of each fork = area of termination at beam end × .6.

For the proportions of brasses, cotters, and gibs, see Miscellaneous.

Crank Shaft.

Diameter = diameter of piston rod × 2.5.

Cranks.

In beam engines this crank is under the same misfortune as the beam, viz., constructed of cast iron; also, it is large and heavy in ratio to the symmetrical contour which wrought iron will admit of, combining the same strength. As, however, the prejudice of some makers has to be gradually eradicated, the author presents the fol-

lowing proportions of cast and wrought iron cranks:

CAST IRON CRANKS.

Diameter of boss of pin = diameter of pin × 2.

Diameter of crank shaft boss = diameter of shaft × 1.75.

Length of bosses = diameter of shaft or pin.

Thickness of web = length of boss for shaft × .8.

Thickness of centre rib = thickness of web × .6.

Depth of web = thickness of web.

WROUGHT IRON CRANKS.

Thickness of metal of boss around shaft = diameter of shaft × .4.

Thickness of metal of boss around pin = diameter of pin × .375.

Area of crank at centre = area of shaft.

This crank should be shrunk on the shaft, after which keyed, thus ensuring a permanent connection.

Gear for Working Slide Valve.

The slide valve being used only in beam engines of small power, a brief notice will only be given, sufficient, however, to enable the proper proportions to be attâinable. The mode of working the slide is by an eccentric, keyed on the crank shaft, whose motion is transmitted by a rod, levers, and weigh shaft to the valve.

Outside lap of valve = width of port supply × .5 to .6.

$$\text{Inside lap} = \frac{\text{outside lap}}{6}$$

Width of bar in cylinder = outside lap + inside lap + width of supply port.

Diameter of valve rod = piston rod × .5 to .4.

Throw of eccentric = outside lap + width of supply port, presuming all levers are of the same length.

Diameter of eccentric bolts = diameter of valve rod × .8.

Width of eccentric band = bolts' diameter × 2.1.

Thickness = bolts' diameter × .8.

$$\text{Thickness of eccentric boss} = \frac{\text{diameter of shaft}}{5 \text{ to } 6}$$

Thickness of band = thickness of boss × .75 to .6.

ECCENTRIC ROD.

As this rod is of great length, even in engines of a moderate size, where direct action from the shaft to the valve lever is observed, rigidity is required, so as to transmit a true motion to the valve; but this rod is not subject to such strains as the general modes of construction and proportions would infer; being flat bars, the sectional area of each equals that of the valve rod; also being strengthened by perpendicular stays of huge dimensions, intersected with lattice-work,

sufficient to bear ten times the strain the eccentric can ever impose on it, thus making a girder instead of a rod, and thereby incurring unnecessary weight and friction. The following proportions will be found to be of practical utility:

The form of the eccentric rod should be thus: a rod should be keyed or bolted centrally in, or to the eccentric band, as for marine or high pressure engines, the eccentric bolts being prolonged as stays, and secured to the rod at the valve end by bolts and nuts, or rivets.

The area of the eccentric rod at shaft end = area of valve × 1.2.

Area at valve end = area of valve rod.

Increase of diameter at centre = $\frac{1}{32}$ per foot of length.

Diameter of eccentric bolts at centre, used as stays = diameter of valve rod.

Where two valves are used, as in high and low pressure engines combined, the united areas of the valve's rods must be observed.

When mitre gear, cams, etc., are used to impart motion to the valves, originating from the crank shaft, a mitre wheel is keyed on it, working its companion keyed on a weigh shaft, the latter being either horizontally, or at an angle to suit the position of the cam shaft, on which is also keyed a second set of mitre gear.

Diameter of gear shaft = diameter of cam shaft × 1.3 to 1.2, according to its length.

Pitch of mitre gear = $\frac{3}{4}$ inch per foot of diameter of pitch line.

As the mitre wheel on the crank shaft is usually in halves, the connection will determine its diameter.

The cam shaft mitre gear should be as small as practical, as it is usually boxed or cased.

FLY WHEEL.

This wheel in beam engines being large and heavy, for practicability in moulding, and casting, the rim is in segments, the centre and arms separate, connected by bolts and nuts, and adjusted by keys.

Diameter of wheel = stroke of engine × 3. to 2.5.

Weight of rim (cwts.) = power of engine × 2 to 3.

$$\text{Depth of rim} = \frac{\text{radius of rim}}{8 \text{ to } 10}$$

Number of arms = 6 to 8.

$$\text{Sectional area of each arm} = \frac{\text{area of rim}}{4}$$

Width of arms at rim = depth of rim × .7 to .8.

Taper of arms = $\frac{1}{2}$ to $\frac{5}{8}$ of an inch per foot of length.

$$\text{Diameter of centre} = \frac{\text{diameter of wheel}}{5}$$

Diameter of arm bolts $= \frac{3}{32}$ to $\frac{1}{16}$ of an inch per foot of diameter of rim.

Width of keys = bolt's diameter × .4.

Thickness of boss of centre = diameter of shaft × .4.

Length of boss = diameter of shaft × 1.75.

Thickness of body of centre $= \frac{\text{thickness of boss}}{3}$

Thickness of ribs = thickness of body × .75.

Wrought iron rings should be shrunk on the extremities of the boss so as to strengthen it.

Thickness of ring $= \frac{\text{thickness of boss}}{3}$.

Width of ring = thickness × 2.

Cubic contents of condenser =

$$\frac{\text{cubic contents of cylinder}}{6 \text{ to } 7}$$

Cubic contents of air pump, single acting =

$$\frac{\text{cubic contents of cylinder}}{6 \text{ to } 7}$$

Cubic contents of feed pump = as for high pressure engines.

Diameter of air pump rod $= \frac{\text{diameter of pump}}{6 \text{ to } 8}$

Diameter of feed pump rod =

$$\frac{\text{diameter of pump plunger}}{2 \text{ to } 3}$$

MARINE SCREW ENGINES.

Marine engineering has become a world of itself in a professional sense of the term, for as we advance in science and art, rapid improvement takes place. To the uninitiated it may perhaps seem but slow, the alteration being only in detail, which, practically, is the most essential to eradicate the evil from the whole. England and Scotland have produced the best marine engines in the world, each maker or firm of course having his or their particular design, class, etc., etc. Scotland produces fine specimens of engines, combining strength and utility, but not equal on the whole to England. The London engineers are undoubtedly the *ne plus ultra*, in every sense of the word, relative to marine engines. First on the list stand Messrs. Penn, for their well known double trunk engine, beautiful in design and proportion, but perhaps to the eye light or scanty in material, showing evidently that this firm carefully calculate the required strength of each detail to the most minute exactitude. One observation must be added, Messrs. Penn's engines are models for the most competent and conversant to dwell on.

The next great firm is the Messrs. Maudslay; their class of engines are, generally, the usual double piston rod, return connecting rod, with two slide valves, and casings to each cylinder. In design the Messrs. Maudslay are certainly faultless,

but a doubt has often arisen in the mind of the author whether the proportions by this talented firm are not too heavy—a fault certainly on the right side. This firm has lately produced a new arrangement of engines, and valve gear, having three cylinders instead of two, thereby equalizing the reciprocity of the action of the pistons.

Attention is now directed to a firm of high standing and good repute, none producing better arranged or proportioned engines than Messrs. Ravenhill, Salkeld, and Co., they being the originators of the double piston rod return connecting rod arrangement, and well and truly have they adhered to the task they undertook—viz., to produce a first class example in the fullest sense of the word.

Messrs. Humphrey, Tennant, and Co. produced at the great exhibition (1862) a splendid example of engines, adapted for the screw, of the single piston rod type, direct acting. This arrangement is certainly worthy of attention from all who are interested—viz. for the single piston rod, guide, solid link, and short connecting rod of splendid proportion, combining faultless design, with the position of the suction and delivery valves, in the condenser and air pump, the whole worthy of copying, but query if to be improved on. Last, but not least, the engines produced by the Messrs. Rennie, of the single trunk kind, having a connecting rod on the same crank to work a single

trunk plunger for the air pump, single acting; the cylinders are not side by side, as arranged by other makers, but opposite each other, with the condenser and air pump, the latter being worked by the opposite engine. Such arrangement is, of course, a great saving of room, a great desideratum in steam-ships. This firm shows great perception and care, in their design and proportion, being both a credit to the age we live in.

The author may be excused for mentioning his invention—viz., the anti-friction trunk engine—Burgh and Cowan's patent. This engine occupies less space at a given horse power, than any direct acting engine universally used, combining economy and durability, by the means of bringing the centre of the connecting rod in the centre of the piston, vertically, and horizontally, also non-exposure and friction of the trunks, and no loss of area in the cylinder, attainments never before accomplished, thus dispensing with an immense weight and cost of machinery.

The rules for the marine engine will now be fully elucidated in the most practical form. Singular as it may appear, but true it is, that each maker differs in the area of their cylinders at a given nominal power. The Admiralty rule demands the speed of the piston in their formula; consequently, the higher the speed determined and agreed on, the smaller the diameter of the cylinder. The author has carefully compiled the fol-

lowing table, being the average results produced by the leading firms, amalgamated with his own experience in this branch of the profession:

Nominal HP			Square inches per HP.		
20	to	40 = 20	to	18.5	for one cylinder
50	"	100 = 18	"	17	
150	"	200 = 16.6	"	16	
250	"	300 = 15.72	"	15.3	
450	"	500 = 14	"	13.5	

Ratio of length of stroke to diameter of cylinder: In small engines from 50 HP to 200 HP collectively, the ratio $= \dfrac{\text{diameter of cylinder}}{1.4 \text{ to } 1.6}$

Engines from 250 HP to 450 HP collectively $= \dfrac{\text{diameter of cylinder}}{1.65 \text{ to } 1.78}$

Engines from 500 HP to 900 HP collectively $= \dfrac{\text{diameter of cylinder}}{1.8 \text{ to } 1.87}$

Engines from 1000 HP to 1500 HP collectively $= \dfrac{\text{diameter of cylinder}}{1.93 \text{ to } 2.}$

These proportions will produce the desideratum at the length of stroke usually adopted. See Table below:

Nominal HP collectively.		Diameter of each cylinder.		Length of stroke. ft.	in.		Divisor.
60	...	26½	...	1	6	...	1.472
100	...	38	...	2	0	...	1.583
200	...	46⅝	...	2	6	...	1.554

Nominal HP collectively.		Diameter of each cylinder.		Length of stroke ft.	in.		Divisor.
300	...	58	...	2	9	...	1.757
400	...	64	...	3	0	...	1.777
500	...	70¾	...	3	3	...	1.814
600	...	76½	...	3	6	...	1.821
800	...	84½	...	3	9	...	1.875
1000	...	92¾	..	4	0	...	1.932

CYLINDER.

Thickness of metal of cylinder:

HP of one cylinder.		Diameter.		Thickness.	
30	...	26½	...	¾	add ⅛ for re-boring.
50	...	38	...	⅞	
100	...	46⅝	...	1	
150	...	58	...	1⅛	
200	...	64	...	1¼	
250	...	70¾	...	1$\frac{5}{16}$	
300	...	76½	...	1⅜	
400	...	84½	...	1½	
500	...	92¾	...	1¾	

Thickness of metal of steam passages = thickness of body × .6 to .8. Use the latter in small engines.

Thickness of flanges = thickness of the body.

Diameter of flange studs = 1 to 1½ inch.

Pitch of bolts. See Miscellaneous.

Thickness of cover = thickness of metal of steam passage.

Thickness of ribs $=$ thickness of cover $\times$ .8 to .7.

Diameter of man hole $=$ 16 inches as a maximum.

Area of port supply for slide valve $= 1$ to $\frac{3}{4}$ of a square inch per HP nominal.

Length $=$ diameter of cylinder $\times$ .7 to .6.

$$\text{Width} = \frac{\text{area}}{\text{length}}$$

Width of bar $=$ outside lap of slide valve $+$ inside lap $+$ width of port supply.

Exhaust port width $=$ width of supply port $\times$ 1.5.

Common Slide Valve.

Outside lap $=$ width of supply port $\times$ .6.

$$\text{Inside lap} = \frac{\text{outside lap}}{8}$$

In cases where the stroke of the valve admits the steam at a lesser area than it exhausts from the same port into the condenser, the following must be observed:

Area of opening, or travel of valve from edge of port $= 1$ to $\frac{3}{4}$ of an inch per HP.

Area of port $=$ area of opening $\times$ 1.5

Area of exhaust $=$ area of port $\times$ 1.5.

Width of bar in cylinder $=$ width of outside lap, minus inside lap $+$ width of supply port.

Outside lap $=$ width of opening $\times$ .6.

$$\text{Inside lap} = \frac{\text{outside lap}}{8}$$

In order to reduce the friction as much as possible, narrow bars are used in the cylinder, both for the common, and equilibrium valves. The following will enable the most practical proportions to be obtained:

COMMON SLIDE.

Width of bar = width of port × .5, but one inch as a minimum.

Lap of valves as before given.

Width of exhaust space in valve = width of port supply × 1.5 + half the travel of the valve + width of bar, minus inside lap.

Width of exhaust port in cylinder = width of bars, minus inside laps, deducted from the width of exhaust space in valve.

EXHAUST RELIEF SLIDE VALVE.

This valve allows the steam to exhaust a greater area than that of the supply.

Width of bar = width of opening × .5, but one inch as a minimum.

Width of exhaust space in valve = width of port × 1.5 + half the travel of the valve + width of bar, minus inside lap.

Width of exhaust port in cylinder = width of bars, minus inside laps, deducted from the width of exhaust space in valve.

Equilibrium Slide Valve.

This valve is adopted in large engines for two reasons: firstly, to reduce the stroke, thereby the friction; secondly, to neutralize the pressure of the steam acting on the valve. These valves have double ports for supply, and single for exhaust, corresponding ports being cast in the cylinder. When the valve travels the width of the port, the proportions will be thus:

COMMON EQUILIBRIUM SLIDE.

Lap of valve as before given.

Small bar = width of bar as before.

Width of exhaust space in valve = width of 2 ports' supply × 1.5 + half travel of the valve + width of small bar, minus inside lap.

Width of large bar = outside lap + width of port + width of small bar + half travel of the valve.

Width of exhaust port in cylinder = width of bars, minus inside laps, deducted from the width of exhaust space in valve.

Exhaust Relief Equilibrium Slide Valve.

Laps as before given.

Width of exhaust space in valve = width of 2 ports' supply × 1.5 + half travel of the valve + width of small bar, minus inside lap.

Width of small bar = width of port supply × .5 but one inch as a minimum.

Width of exhaust port in cylinder = width of small bar, minus inside laps, deducted from the width of exhaust space in valve.

Width of large bar in cylinder = outside lap + width of opening caused by valve + width of small bar + half travel of valve.

Half travel of valve = width of opening or port + outside lap.

$$\text{Width of face beyond port} = \frac{\text{half travel of valve}}{2}$$

Thickness of body of valves = $\frac{5}{8}$ to $\frac{7}{8}$ of an inch. Ribs should be cast in valves, exceeding 12 inches in length.

Space between ribs (maximum) = 12 inches.

Space between ribs (minimum) = 6 inches.

Thickness of ribs = thickness of body × .8 to .7.

Thickness of flange of valve = thickness of body × 1.25 to 1.

Diameter of valve rod = diameter of piston rod × .4.

Position of the valve rod should be in the centre of the valve (front and plan).

Width of guide of valve in casing = $\frac{3}{4}$ to $1\frac{1}{4}$ inch

The means for ensuring the slide valve's working against the facing on the cylinder are numerous. In small valves, springs are used, 3, to 4, branches equidistant, secured in the centre by one or two studs, $\frac{5}{8}$ to $1\frac{1}{4}$ inches diameter in valves, for engines to 50 HP, collectively; above this power

the means adopted are as follows: The sides of the valve are raised either square and plained, or circular and turned above the top of the metal of steam passage, cased with a brass bush; a sliding ring of cast iron or gun metal embraces either the round or square part of the valve, as the case may be. This ring is recessed within another packed with a gasket, which ring is raised or lowered by set screws, or studs, screwed into gun metal blocks, dovetailed in the body of the slide valve. These studs are prevented from unscrewing or becoming loose by a small ratchet pinion cast with the stud, having a spring secured to the slide valve; the spring also acts as an indicator of revolutions, so that the studs may be equally screwed when the compression of the packing is required; a communication with the condenser to the back of the slide valve prevents an excess of pressure.

Width of slide ring = diameter of valve rod × .7 to .6.

Thickness of slide ring = width × .8 to .7.

Thickness of packing ring at sides under recess =

$$\frac{\text{thickness of the sliding ring}}{2 \text{ to } 3}$$

Depth of recess in packing ring = width of the slide ring.

Diameter of set studs = width of slide ring × .6.

In square packing slide rings, the studs should

be arranged 2 at the ends, and from 2 to 4 at the sides, care being taken that the studs at the angles of the slide valve be equidistant. In round slide rings they are divided into 6 or 8 parts to equal the number of studs. In most cases the pitch of the studs = diameter of stud × 14 to 16.

The author recommends steam as the best means to cause the slide valve to retain its position against the face of the cylinder without undue pressure, thus: the steam acts against two flat sliding pieces of gun metal introduced or recessed in the cover of the casing, provisions being cast thereon to receive the same. On the back of the slide projections are cast to correspond with the pieces alluded to; the cover of the casing has a communication from one recess to the other, the steam being admitted from the slide casing by a cock, another being in the lower recess to let off the condensed steam. When starting the engine, the supply and discharge cocks should both be open; on the latter being closed, the former will regulate the pressure on the valve with the most minute exactitude.

Valve Casing.

Thickness = the thickness of the body of the cylinder × .75 to .6.

Diameter of bolts or studs = $\frac{5}{8}$ to $\frac{7}{8}$ of an inch.

Pitch of bolts. See Miscellaneous.

Thickness of flanges = thickness of body × 1.12.
Thickness of cover of casing = thickness of body.

The flanges of the casing should be ribbed between each stud or bolt.

The cover of the casing should be ribbed horizontally and vertically.

The area between the ribs should never exceed 1 square foot per 20 lbs. of steam per square inch on the piston.

Thickness of the ribs of flanges = thickness of the body of casing.

Thickness of the ribs of cover = thickness of the body of the casing × .8 to .7.

Depth of the ribs of cover = 3 to 5 inches.

Diameter of securing studs of cover = thickness of cover.

Piston.

The best mode of rendering the piston steam tight is by metallic means—viz., by a ring of cast iron as a spring, the external periphery of which coincides with the internal of that of the cylinder, the ring being of uneven thickness, and divided at the thinnest part at an angle of 45°, having a tongue or piece of gun metal dovetailed in its centre, so as to prevent the steam from passing through the division; the ring is rendered effective by a packing of gasket, which is com-

pressed by a face ring and studs; in some cases a separate ring with separate studs. Each of the studs should be prevented from unscrewing by a rachet forged on the stud, having a spring secured to the face ring of the piston.

RULES.

Depth of the piston $= \dfrac{\text{diameter of cylinder}}{9 \text{ to } 10}$

Thickness of body = thickness of cylinder × .8. to .7.

Thickness of metal around rods = thickness of body × 2.

Thickness of ring opposite slit = thickness of body.

Thickness of ring at slit = thickness of body × .6 to .7.

Taper of ring spring internally = 2 inches per foot.

Width of packing ring = thickness of spring ring at slit × 2.

Diameter of packing ring studs = $\frac{5}{8}$ to $\frac{7}{8}$ of an inch.

Diameter of face ring studs = $\frac{3}{4}$ to 1 inch.

Width of face ring = diameter of studs × 1.8.

Thickness of face ring = thickness of body. This ring is recessed to receive the heads of the packing ring and securing studs.

Position of stud blocks = centre of depth of piston.

Thickness of blocks = diameter of stud.
Side of square of block = diameter of stud × 1.8.
Proportion of valve rod stuffing box = as for piston rod, with the exception of studs, which in this case = diameter of rod × .38 to .3.

$$\text{Piston rod's dia. (2)} = \frac{\text{diameter of cylinder}}{9 \text{ to } 11}$$

Diameter of stuffing box = diameter of rod × 1.5.
Depth of stuffing box = diameter of stuffing box × .6 to .5.
Depth of gland = depth of stuffing box × .75 to .6.

Beyond the gland or cast with the bush should be an oil chamber.

Diameter of oil chamber internal = diameter of gland.
Depth of oil chamber = diameter of piston rod × .25 to .3.
Thickness of metal of oil chamber = $\frac{1}{8}$ to $\frac{3}{8}$ of an inch.
Depth of stuffing box beyond oil chamber = from 1 to 2 inches.
Diameter of gland is as large as the external diameter of the oil chamber will admit of.
Diameter of studs for main gland (3 to 4) =

$$\frac{\text{diameter of piston rod}}{4 \text{ to } 6}$$

CONDENSER.

Cubic contents for one cylinder $=$

$$\frac{\text{cubic contents of cylinder}}{6 \text{ to } 7}$$

For two cylinders $=$

$$\frac{\text{cubic contents of cylinder} \times 1.5}{6 \text{ to } 7}$$

Thickness of body $= \frac{3}{4}$ to $1\frac{3}{8}$ of an inch, being ribbed, and in some cases stayed for large engines.

Thickness of securing flanges $=$ thickness of body $\times$ 1.25.

Thickness of doors $=$ thickness of body $\times$ .8 to .7.

Diameter of securing studs $=$ thickness of metal of doors.

AIR PUMPS.

Cubic contents, double acting $=$

$$\frac{\text{cubic contents of cylinder}}{10. \text{ to } 12.}$$

Cubic contents, single acting $=$

$$\frac{\text{cubic contents of cylinder}}{6. \text{ to } 7.}$$

Stroke of pump $=$ stroke of engine.

Area of valves $=$ area of pump $\times$ .75 to .8.

VALVES.

These valves are discs of vulcanized India-

rubber; the average diameter is about 6 to 7 inches, but it should never exceed 9 inches.

Thickness of valve $= \frac{1}{2}$ to $\frac{3}{4}$ of an inch.
Lap of valve $=$ thickness $\times .5$.

$$\text{Lift of valve} = \frac{\text{diameter}}{4}$$

Valve Seating.

Thickness of flange $=$ thickness of valve $\times .8$ to $.75$.

Diameter of securing studs $=$ thickness of valve.

Pitch of studs $=$ diameter of stud $\times .8$ to $.7$.

Area of each small opening in seatings should never exceed 2 square inches.

Thickness of ribs $= \frac{1}{8}$ of an inch per square inch of opening.

Depth of ribs $= \frac{1}{8}$ of an inch per inch of extreme diameter of opening.

Diameter of securing bolts for guard $= \frac{3}{16}$ to $\frac{1}{8}$ of an inch per inch of valve's diameter.

Diameter of securing bolt boss in seating $=$ diameter of stud $+$ twice the lap of valve.

Radius of curve of guard $=$ diameter of valve $\times .6$ to $.5$, but in some cases the guard is angular.

Thickness of guard $= \frac{1}{8}$ to $\frac{1}{4}$ of an inch.

An approximate mode to obtain the effective area of the openings in one valve seating $=$ area of the diameter of the opening $\times .5$ to $.6$, the latter being for diameters from 5 to 7 inches.

$$\text{Total area of diameter of opening} = \frac{\text{effective area}}{.5 \text{ to } .6}$$

The arrangement of the valve seatings is various. In some cases one valve plate, containing one set of valves, is used, but the preferable plan is to make each valve seating separately, secured by 4 separate studs, or by the guard bolt, with a cross bar on the opposite side of the metal of the condenser; the diameter of the bolt would have to be increased, say 1½ times of the bolt's diameter when securing the guard only. The gain by having each valve seat separately is a saving of patterns, and ensuring a more perfect joint in relation to the connection of the air pump and condenser. The positions of the suction and discharge valves are various; the most modern and practically correct arrangements are thus: The suction valves are inverted in the bottom of the condenser, so as to effectually drain the same; the discharge valves are on the same level, but not inverted; longitudinally, the valves are arranged the whole length of the condenser, transversely, being two to three in number. In the case of the discharge valves, there is generally an increase of one valve in number with valves of the same diameter as the suction, but a better plan is to increase the area slightly for the discharge valves, and retain the same number as for the suction.

As air ascends in water when the latter is com-

pressed, the author has devised an arrangement of valves to allow the air to ascend, and the water (assisted by its gravity) to descend. The following description will enable the interested readers to practically understand the desideratum obtained. The suction and discharge valves are inverted, the former over the air pump, and the latter under; over the air pump at each end there are two air valves, reverse in action, but the same in principle as all the others, for example, when the air pump is discharging itself, the air valves open upwards whereas the discharge valves open downwards, but both effectually cause a vacuum in the air pump, immediately the return or reverse action takes place. By this arrangement, the condenser, the air pump, and valves occupy less space than any other yet introduced; this is illustrated in general arrangement and detail in the author's practical illustration.

Area for exhaust steam pipe for 2 cylinders = area of exhaust port from one cylinder × 1.5 as a maximum, 1.25 as a minimum.

Area of injection (sea-water) for 2 cylinders = cubic contents of one cylinder in feet × 1.5 as a minimum, 2 as a maximum × the pressure of steam per square inch used as decimals.

The bilge injection is used only when the sea injection pipe or valve is disarranged. The area of the bilge injection is usually smaller than that from the sea.

Air pump lining is usually of gun metal, secured either by a flange, with studs, or a packing provisiòn cast in the condenser; in some cases studs of gun metal $\frac{1}{2}$ inch in diameter are recessed in the lining, and tapped into the condenser; by this means the flanges and packing are dispensed with.

Thickness of lining $= \frac{1}{4}$ to $\frac{1}{2}$ an inch, with provisions for turning and fitting.

Air pump piston, or plunger, is entirely of gun metal with metallic packing rings and studs, as for the steam piston.

Depth of piston $=$ diameter $\times$ .3 to .2.
Thickness of metal of body $= \frac{3}{8}$ to $\frac{1}{2}$ inch.
Thickness of ribs 4 to 6 $=$ thickness of body $\times$ .7 to .6.

$$\text{Diameter of air pump rod} = \frac{\text{diameter of piston}}{\text{6 to 7.}}$$

Proportions of stuffing box as for piston rod
Area of exhaust (water) for 2 air pumps $=$ total area of one set of valves for one air pump $\times$ 1.5.
Area of snifting valve $=$ 1 to $\frac{3}{4}$ of a square inch per foot of cubical contents of condenser.

INJECTION VALVE.

This valve regulates the water from the sea, or bilge Kingston valves. The injection valve and

casing are made entirely of gun metal, the valve and seat are of a gridiron shape, with 3 or 4 openings.

Length of openings = diameter of pipe.

$$\text{Width of each opening} = \frac{\text{area of one opening}}{\text{length}}$$

Thickness of metal of body = $\frac{1}{4}$ to $\frac{3}{8}$ of an inch.

Thickness of flanges = thickness of body $\times$ 1.125.

Diameter of valve rod = $\frac{3}{32}$ to $\frac{1}{8}$ of an inch per inch of diameter of pipe.

Diameter of studs = $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

Feed Pump.

This pump, as in the case of high-pressure engines, is subservient to the pressure of the steam and cubic contents of the cylinder. The length of the stroke of pump is, in direct acting, trunk, and return connecting rod, engines, equal to the stroke of the engine.

Cubic contents of pump in inches = cubic contents of cylinder + cubic contents of one steam passage in feet $\times$ 3 times the number of cubic inches of water to produce one cubic foot of steam. See Table below.

Pressure of Steam per square inch			Cubic inches of Water to 1 cubic foot of Steam.
10	...	...	1.7
15	...	...	2.0
20	...	...	2.3
25	...	...	2.6

Pressure of Steam per square inch.			Cubic inches of Water to 1 cubic foot of Steam.
30	...	...	2.9
35	...	...	3.2
40	...	...	3.5
45	...	...	3.8
50	...	...	4.0
60	...	...	4.6
70	...	...	5.1
80	...	...	5.65
90	...	...	6.2
100	...	...	6.68

$$\text{Area of plunger} = \frac{\text{cubic contents of pump}}{\text{stroke}}$$

$$\text{Thickness of plunger} = \frac{\text{diameter}}{8 \text{ to } 9}$$

$$\text{Area of pump rod} = \frac{\text{area of plunger}}{4}$$

$$\text{Area of a feed valve} = \text{area of plunger} \times .8.$$

The valves for the feed pump are as for the air pump, one only being used for suction and one for discharge.

GUIDE BLOCK.

This block is of various forms, each maker of course being ready to assert his own as the best. The following is a synopsis of some of those at present used: First, the connecting rod is a single end, with a cross head connected to the piston

rods, having brass blocks secured on the cross head on both sides of the connecting rod, or between the connecting and piston rods; the guides are of cast iron, secured at each end by bolts and nuts. Such a system, or rather arrangement, however, owes its origin to the antique high pressure engine, with its long cross head, and double instead of single end connecting rod. The next in use is the same kind of cross head, secured in a block of cast iron, but in small engines, of brass or wrought iron, the underside of this block is of a dovetailed form in section, and works in a channel on the air pump casing, or a framing cast separately and secured to it. The last and best is that improved arrangement known by the name of the T guide block, secured by bolts and nuts to the cross head at its back, to which cross head the piston rods are secured in the usual manner; the connecting rod is forked, with the connecting pin riveted in it; the block is either in halves perpendicularly, or solid at the back, with the front part loose between the securing bolts; the T or guide part is cast with the upper, having a separate bottom, designated the shoe, which has a taper in its connection, so that adjustment by studs is attainable without disarrangement.

COMMON GUIDE BLOCKS.

$$\text{Length} = \frac{\text{stroke of engine}}{3 \text{ to } 4}$$

$$\text{Width} = \frac{\text{length}}{2 \text{ to } 3}$$

Thickness of metal over and under cross head =

$$\frac{\text{diameter or width of cross head}}{4 \text{ to } 5}$$

Thickness of body of top part of guide = $\frac{3}{4}$ to $1\frac{1}{4}$ inch.

Thickness of ribs = thickness of body × .8 to .7.

Diameter of securing bolts at each end (2) = thickness of body.

T Guide Block and Cross Head.

Area of guide = area of cylinder in square inches × pressure

$$\frac{\text{of steam in lbs. per sq. inch on piston as decimals}}{\text{ratio of connecting rod to stroke}}$$

Length of guide = stroke × .6.

$$\text{Bottom width of guide} = \frac{\text{area of guide}}{\text{length}}$$

$$\text{Thickness of guide} = \frac{\text{width}}{4 \text{ to } 6}$$ but the minimum thickness = $1\frac{1}{4}$ inch.

$$\text{Top width of guide} = \frac{\text{bottom width}}{3 \text{ to } 4}$$

$$\text{Area of each securing bolt} = \frac{\text{area of piston rod}}{2}$$

$$\text{Thickness of metal around bolt} = \frac{\text{diameter}}{8}$$

Diameter of bolt head = bolt × 1.5.

Thickness of head $= \frac{\text{diameter of bolt}}{2}$

Diameter of pin = diameter of piston rod × 1.25.
Diameter of bearing = diameter of pin.
Length of bearing = diameter of bearing × 1.25.

Thickness of metal (back) $= \frac{\text{bearing's diameter}}{3}$

Thickness of metal (front) = thickness of back × .6.

Thickness of projection $= \frac{\text{thickness of back}}{2}$

Diameter of set screw of shoe $= \frac{\text{width of guide}}{10}$

Thickness of cap $= \frac{\text{bearing's diameter}}{2}$

Width of cap = size of nut across the angles × 1.1.
Sectional area of cross head = area of piston rod × 1.5.
Width = diameter of head of bolt, or width of cap.

Thickness of clip of cap $= \frac{\text{diameter of bolt}}{4}$

Guide Frame.

This frame is either cast on the condenser or separately, and secured by bolts and nuts. When for single piston rod engines, the guide frame is secured in front of the cylinder, to each of the main frames of crank shaft; the top part of the

guide channel is generally cast separately, designated the flange, and secured by bolts and nuts to the lower part.

Thickness of flange = depth of channel × .8 to .7.
Thickness of bottom of channel = thickness of flange.
Diameter of flange securing bolts = thickness of flange × .8 to .7.
Pitch of bolts = diameter of bolts × 10.
Thickness of metal of body and ribs = ¾ to 1¼ of an inch.
Width and depth of ribs = thickness × .7 to. 6.
Thickness of flanges = thickness of ribs × 1.25.
Diameter of securing studs or bolts = thickness of flanges.

When the feed and bilge pumps are cast with this frame, the proportions will be as follows:

Diameter of barrel = diameter of plunger + ¾ to one inch.
Thickness of barrel of pump = ½ inch as a minimum for 1½ inch diameter, above this ¼ of an inch per inch of internal diameter.
Depth of stuffing box = diameter of plunger.
Depth of gland = depth of stuffing box × .75.
Diameter of stuffing box = diameter of plunger × 1.375 to 1.3.
Thickness of metal of stuffing box = thickness of gland.

$$\text{Diameter of gland bolts} = \frac{\text{diameter of plunger}}{4}$$

Thickness of flange of gland = diameter of bolt.

Proportions for plunger rod stuffing box = that for air pump rod.

Connecting Rod.

This rod is of two kinds, double or forked at the cross head end, the crank end, with solid head in halves, and hexagonal brasses secured by bolts and nuts; the other kind being a single T at each end, with the flat brasses and caps secured by bolts and nuts. The proportions of the former or double end connecting rod will be as follows:

Length = stroke × 2.5 to 3.

$$\text{Cap bolt area} = \frac{\text{piston rod area}}{2}$$

Diameter at guide end = diameter of piston rod.

Diameter at crank end = diameter of piston rod × 1.25.

Diameter at centre of turned part = $\frac{1}{8}$ inch per foot of length + diameter at crank end.

Diameter of guide block pin = diameter of piston rod × 1.25.

Area of each fork = area of piston rod × .75.

Width of each fork = diameter of piston rod × 1.25.

$$\text{Thickness of each fork} = \frac{\text{area}}{\text{width}}$$

Space between forks = diameter of pin × 1.25.

Diameter of eye =

$$\frac{\text{diameter of pin} \times 2 + \text{pin's diameter}}{3}$$

Width of eye = thickness of fork × 1.5.

Length of fork from centre of eye = pin's diameter × 2.

Thickness of brass $= \dfrac{\text{diameter of bearing}}{8}$

Thickness of caps $= \dfrac{\text{diameter of bearing}}{8}$

Diameter of head of bolt = diameter × 1.5.

Thickness $= \dfrac{\text{diameter}}{2}$

Single Ends Connecting Rod.

Diameter of cross head = diameter of piston rod × 1.4.

Space between brasses and side of securing bolts = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

The remaining proportions are as those already given.

Slide Valve Link Motion.

The principal part in this motion is the link, it being generally slotted or hollow, as for locomotive engines.

Area of slide block pin = area of valve rod × 1.25.

Sectional area of each bar of link (square) = area of valve rod × 2.

Thickness of block beyond pin's diameter =

$$\frac{\text{pin's diameter}}{5 \text{ to } 7}$$

Thickness of flanges of block $= \dfrac{\text{pin's diameter}}{7 \text{ to } 9}$

Length of sliding block ≐ diameter of pin × 2.5.

Distance between centres of eccentric rod's pins = stroke of slide valve × 2.5 to 3.

Area of eccentric pin = area of slide valve rod × 1. to .875.

Area of eccentric rod at centre = area of slide valve rod.

Width of eccentric rod at link end = diameter of pin × 1.25.

Taper of eccentric rod = ¼ to ⅜ inch per foot in length.

Area of securing bolts to eccentric band = area of valve rod × .7 to .6.

Thickness of T head = diameter of securing bolts.

Solid Link.

This link is an improvement on the slotted or hollow link; being solid it is of course much stronger, and consequently of less area than the usual kind.

Area of solid link = area of slide valve rod × 2.7 to 2.5.

Thickness of link = diameter of valve rod × 1.25.

The author has designed a solid link and block, which allows the centre of the eccentric rod to be in the centre of the valve rod horizontally and vertically; thus, the link is double or slotted at the ends, so as to allow the eccentric rod to be inserted in it, instead of clasping it as usual; the pins are riveted in the link, so that the surface is unbroken throughout; the link works in a block of gun metal, which oscillates, or vibrates, on projections cast on both sides; these projections work in the valve rod, which is so formed with bushes to receive the projections on the block; one part of the valve rod is secured by studs, so that the block can be fitted, and replaced by a new one when worn. This arrangement is shown in the author's practical illustrations. The following are the proportions of the block and provision on valve rod.

Length of sliding block = width of link × 1.5.
Thickness of block, front, back, and sides = width of link × .3 to .2.
Diameter of projections = diameter of valve rod.
Length of projection = diameter of projection × .7 to .6.
Width of portion secured to valve rod = diameter of projection × 2.

Diameter of securing studs (3) = $\frac{\text{diameter of slide valve rod}}{2 \text{ to } 3}$

ECCENTRIC, BANDS, RODS, BOLTS, ETC.

Diameter of valve rod = diameter of piston rod × .4.

Area of solid link pin = area of valve rod × .7 to .8.

Area of band bolts = area of pin × .75.

Width of band = nut across angles × 1.03.

Thickness of boss of eccentric = $\frac{\text{diameter of crank shaft}}{6 \text{ to } 8}$

Thickness of rim and arms = thickness of boss × .75.

Depth of recess = $\frac{\text{rim thickness}}{4 \text{ to } 5}$

Width of rim, arms, and boss = depth of recess × 2 + width of band.

Thickness of band, wrought iron = diameter of bolts × .6, gun metal × .75.

Thickness of internal brass hoop = thickness of band × .2.

Width of projection = width of band × .4.

Diameter of eye of rod = that of pin × 2.

Width of eye = width of solid link × .5.

Area of eccentric rod at eye = area of valve rod × .8.

Width of rod = diameter of pin × 1.8.
Taper = ½ inch per foot.

Thickness at eye $= \frac{\text{area}}{\text{width}}$.

Thickness at band = thickness at eye × 1.5.
Thickness of bolt flange = diameter of bolts.

CRANK AND SHAFT.

Diameter of shaft at bearing = diameter of piston rod × 2.

Diameter of shaft beyond bearing = diameter of bearing × 1.125 to 1.11.

Length of bearing = diameter of bearing × 2.

Diameter of crank pin = diameter of bearing of shaft.

Length of crank pin = diameter of pin × .75.

Area of each crank at centre = area of bearing × .75.

Width of crank = diameter of shaft beyond bearing.

Thickness of crank $= \frac{\text{area}}{\text{width}}$.

Taper of sides of crank = ¾ to 1 inch per foot.

MAIN FRAME.

This frame supports the crank shaft, and retains the rigidity of the cylinder, longitudinally of the engine, but transversely of the ship. The frame

is of cast iron; the form in general is as an A laid on its side, the double end being secured to the cylinder, and the outer end receiving the crank shaft. Some makers cast their frame hollow below the centre line of the shaft, the part above the shaft being strengthened by a wrought iron stay, secured by bolts and nuts to a provision, cast on the cylinder. This seems to be the preferable plan, both as to symmetry and strength. The proportions will be as follows for brasses, bolts, and frames:

Thickness of brasses between flanges $= \dfrac{\text{bearing's diameter}}{8. \text{ to } 10.}$

Length between flanges of brass = total length of brass $\times$ .7 to .6.

Thickness of flange = thickness of brass between flanges $\times$ .7 to .8.

Thickness of brass at ends = thickness of flanges.

Diameter of securing bolts for cap (2) = diameter of those for crank end of connecting rod.

Space between bearing and side of bolt = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Width of bolt keys = diameter of bolt.

Thickness $= \dfrac{\text{bolt's diameter}}{4}$

Diameter of stay = diameter of securing bolt.

Thickness of securing head = diameter of stay $\times$ .5.

Area of one securing bolt for stay $= \dfrac{\text{area of stay}}{\text{number of bolts}}$

Thickness of cap, cast iron = diameter of shaft's bearing × .5.

Thickness of cap, wrought iron = diameter of shaft's bearing × .4.

Thickness of metal of framing beyond bearing = diameter of bearing × .5.

Thickness of metal around securing cap bolts = diameter of bolt × .5.

Thickness of metal of framing = that of the body of the cylinder.

Depth and width of ribs = thickness of ribs × 4 to 3.

Thickness of bottom flange = thickness of ribs × 1.5 to 1.3.

Width of bottom flange = diameter of bearing of shaft.

Diameter of securing bolts or coach screws = diameter of securing cap bolt × .5.

Pitch of flange securing bolts = diameter of bolts × 9.

Thrust Block and Screw Shaft.

This shaft has a series of rings forged on it to resist the pressure or resistance caused by the screw; for example, if a common screw be inserted in a piece of wood, and the screw turned

(provided the wood is secured rigidly on all sides), it will enter, and the head approach to the wood; but should the wood be secured only, so as to be prevented from turning, but allowed to slide, on the screw being turned it will still enter, but the wood will approach the head. So in like manner, the crank shaft having a screw on its extremity, the water acts as the rigid wood; hence the propulsion of the ship and thrust on the shaft. A series of rings on the shaft, as before stated, diffuse the friction, each ring taking its share, but a doubt arises whether the ring nearest the screw does not receive the major part of the thrust. Presuming this to be the case, this first ring should be wider, and the remainder in proportion. Perhaps a better plan would be to increase the hardness of the gun metal at the first and second recesses.

Number of rings on shaft = 6 to 8.

Width of each ring = $\frac{1}{2}$ inch as a minimum for a shaft 4 inches in diameter; above this to 18 inches in diameter $= \frac{\text{shaft's diameter}}{6 \text{ to } 9}$

Space between rings in most cases = width of rings × 1. to .8.

Depth of rings = width × .75.

Thickness of brasses = depth of ring. Each brass should be recessed in the cap and block, so as to prevent the brasses from shifting.

Number of staying recesses = 2. to 4. An approximate rule will be half the number of rings working in brasses.

Number of bolts for securing cap = one on each side for small shafts, say 3 to 5 inches in diameter; above this diameter 2 to 3 bolts are used, the latter for shafts 18 to 24 inches in diameter.

The sectional area of the cap bolt is derived from the area of the crank shaft, although the former has a tensile and shearing strain on it, and the latter crushing and torsion.

Area of total number of bolts =
$$\frac{\text{area of crank shaft}}{9 \text{ to } 11}$$

Thickness of cap and bottom of block =
$$\frac{\text{diameter of shaft}}{3.5 \text{ to } 4.}$$

Depth of cap bolt's lugs, or bosses = diameter of bolt × 3 to 2.5.

Thickness of metal around bolt = diameter of bolt × .6.

Diameter of bolts for securing block and sole plate = diameter of cap bolts.

The bolts for securing block and sole plate = 4 to 6 in number, which also secure the sole plate to frame of ship.

Thickness of sole plate, ribs, and bottom = thickness of block.

Length of sole plate beyond thrust part of block towards engine = diameter of shaft.

Length of block and sole plate beyond block towards screw = diameter of shaft × 3. to 4.

Length of plummer block for shaft = diameter of shaft × 1.5 to 1.3.

Diameter of cap bolts = diameter of thrust block cap bolts × .75.

Thickness of brasses = thickness of that for thrust blocks × .75.

Thickness of cap and bottom of block =

$$\frac{\text{diameter of shaft}}{5 \text{ to } 6}$$

Turning Gear and Coupling.

The use of this gear is to turn the engines without steam, for accessibility to any particular detail, or for lifting the screw from its coupling. The general mode adopted, is a worm working in a toothed wheel, cast on the shaft coupling beyond the main frame.

Diameter of wheel = stroke of engine × 1.5 to 1.8 the latter above 300 HP. In some cases diameter of wheel = stroke of engine × 1.25 to 1.4, the worm being $\frac{1}{9}$ to $\frac{1}{10}$ of the wheel's diameter.

Diameter of worm generally used =

$$\frac{\text{diameter of wheel}}{7 \text{ to } 9}$$

Length of worm = pitch of teeth × 4.

Pitch of teeth = 2 to 3 inches.

Diameter of worm shaft = pitch of the teeth as a general rule.

Diameter of wheel boss = diameter of shaft $\times$ 2.

Thickness of rim and body of wheel = thickness of teeth. For the proportions of the teeth, see Miscellaneous.

Length of boss = diameter of shaft.

Length of arm of rachet lever = stroke of engine $\times$ 3 to 2.5.

Area of coupling bolts = area of shaft at bearing $\times$ .7 to .9.

$$\text{Diameter of bolts} = \frac{\text{diameter of shaft}}{3 \text{ to } 5}$$

Thickness of coupling at pitch line of bolts = diameter of shaft $\times$ .4 to .3.

Thickness of metal beyond bolt = diameter of bolt $\times$ .75.

WROUGHT IRON COUPLINGS.

The modern mode of coupling the shaft between the thrust block, and the stern tube stuffing box, is by a disc of wrought iron forged on each length of shafting.

$$\text{Thickness of disc} = \frac{\text{diameter of shaft}}{3 \text{ to } 5}$$

Area and diameter of bolts as for cast iron couplings.

STERN TUBE AND STUFFING BOX.

The use of this is to allow the shaft to revolve freely without admitting the sea water; the screw

shaft has a tube cast around it in most cases; this mode being preferable to boring the tube, turning the shaft, and forcing the tube on it, which entails studs as a final security. When the tube is cast on or around the shaft, a good plan is to groove the shaft, in one or two opposite parts, thus ensuring the tube not turning on the shaft. The shaft tube is turned only at each end for a given length, the stern tube being bored to correspond; lignum vitæ is sometimes introduced between the tubes, as a means of reducing the friction at the parts in contact or bearing. This is of course an advantage in great velocities, but the necessary renewal of the wood, attended by the disarrangement of the shafting, greatly lowers its practicability. The author advises that the shaft, and stern tubes, be filled with soft or white metal in ribs cast on the inner and outer diameters of the tubes; that belonging to the shaft might always be replaced by harder or softer metals, as the case might require.

Length of provisional bearing, or friction parts at stern end = diameter of shaft × 2.

Thickness of tubes = $\frac{1}{4}$ of an inch as a minimum, and 1 inch as a maximum for shafts 20 inches in diameter, a good rule being

$$\frac{\text{diameter of tube}}{20}$$

Length of stuffing box = diameter of shaft × 2 to 1.5.

Length of gland = length of stuffing box × .2 to .3.
Thickness of gland = $\frac{3}{4}$ to $1\frac{1}{2}$ inch.
Diameter of gland bolt = thickness of gland.
Number of gland bolts = 4 to 6.
Diameter of bolts for securing stern tube $\frac{3}{4}$ to $1\frac{1}{4}$ inch.
Pitch of bolts = diameter × 8.
Thickness of flange = diameter of bolt.

Screw Propeller.

This propeller should be treated as a common screw entering into a body, whether of wood or metal; presuming the part entered to be rigid, the screw will be advancing or receding, whereas when the screw is fixed longitudinally, the part entered will advance or recede according to the motion it receives. To revert to the origin of the screw propeller is not the intention of the author, he being well aware that the subject has been repeated so often, that those desiring practical information pass the pages filled with such useless matter; consequently the desideratum is only here deemed worthy of attention—viz., the proper proportions to accomplish the best result, commencing with the common screw.

Diameter of the screw of course is due to the depth of immersion of the vessel at the stern; the extremity of the blade should be immersed $\frac{1}{10}$ of its diameter, as a guide for setting out the pro-

portions, but practical demonstration proves that in a heavy sea this rule is often deviated from, according to the susceptibility of the vessel to the action which is enforced by the sea. The following rules are deduced from practice, consequently may be relied on:

Diameter of screw = stroke of engine × 6 to 5.
Pitch = diameter × 1.5 to 1.25.
Diameter of bearing = diameter of crank shaft × 1.25.
Diameter of boss = diameter of crank shaft × 1.5.
Width of T coupling = diameter of shaft × .75.

$$\text{Diameter of T coupling} = \frac{\text{diameter of screw}}{5 \text{ to } 6}$$

Length of blade on line of keel =

$$\frac{\text{diameter of screw}}{5 \text{ to } 6}$$

Thickness of blade at boss = 2 inches for a screw 4 feet in diameter, increasing from this $\frac{1}{8}$ of an inch per foot.

$$\text{Thickness of blade at point} = \frac{\text{thickness at boss}}{3 \text{ to } 4}$$

The correct mode to obtain the pitch of the screw is produced from the speed of the ship, deducting therefrom the slip of the screw, which on making one revolution would in a rigid body advance, or recede to, or from it, equal to the pitch; but in the case of water two practical adherents are to be observed—viz., elasticity and friction;

thus the difference of the progress of the ship, in proportion to the progress of the screw, is termed the slip. The ratio of slip to the theoretical progress of the screw is not even; foulness of the bottom of the ship, state of the weather, and velocity, all determine the loss of speed and slip.

Speed of screw per minute = pitch of screw × number of revolutions per minute of engine.

Theoretical speed of ship in knots per hour =

$$\frac{\text{speed of screw in feet per hour}}{6080 = \text{Admiralty knot in feet}}$$

Loss of speed or slip of screw = theoretical speed of ship minus actual speed of ship.

Actual speed of ship = speed of screw minus slip.

To ascertain the actual pitch, required at a given speed of the screw, to produce a given speed of the ship, the rule will be as follows:

Pitch of screw in feet =

$$\frac{\text{actual speed of ship in feet per hour}}{\text{number of revolutions of screw per hour} \times .9 \text{ to } .75}$$

This rule allows a slip or loss of speed of 10 to 25 per cent., 20 per cent. being the average for war ships.

The following table of the nominal HP requisite for screws of given diameters, is deduced from the best results of the present day:

Nominal HP collectively.	Diameter of Screw.	Pitch—Variable.			Nominal HP per foot of Screw's Dia.
	ft. in.	ft. in.		ft. in.	
60	6 0	7 5	to	9 0	10.0
100	8 0	10 0	"	12 0	12.5
150	10 0	13 0	"	15 0	15.0
200	11 0	14 6	"	18 6	18.18
300	14 0	17 6	"	21 6	21.42
400	16 0	20 0	"	24 0	25.0
500	18 0	20 6	"	24 6	27.77
600	18 6	21 0	"	25 0	32.43
800	19 0	22 6	"	27 6	42.1
900	20 0	23 0	"	30 0	45.0
1000	21 0	24 0	"	32 0	47.61

GRIFFITH'S PATENT SCREW PROPELLER.

The object of this screw, being of a variable pitch, is to ascertain the greatest speed obtainable at a given pitch, being a ratio to the displacement and shape of the ship; the centre of this propeller is globular in shape, into which each blade is secured and adjusted. The following rules and Table will be found of practical utility. The rule given for the length of the boss may be deviated from if required:

RULES.

$$\text{Diameter of boss} = \frac{\text{diameter of screw}}{3 \text{ to } 4}$$

Length of boss = diameter of flange + $\frac{1}{2}$ diameter of shank, in some cases diameter of boss.

Diameter of flange of blade = diameter of boss × .5.

Thickness of flange at edge $= \dfrac{\text{diameter}}{20}$

Lap of blade on boss beyond flange $= \frac{3}{4}$ of an inch per foot of diameter of screw.

Width of blade at widest part $= \dfrac{\text{diam. of screw}}{3}$

Width of blade at point $= \dfrac{\text{diameter of screw}}{7}$

Thickness of blade at root $= \frac{1}{8}$ of an inch to each foot's diameter.

Thickness at point $= \frac{1}{6}$ of that at root.

Diameter of shank = diameter of boss × .25.

Metal around shank $= \dfrac{\text{diameter of boss}}{23 \text{ to } 24}$

Metal beyond flange and cotter $= \frac{7}{12}$ of depth of cotter.

Width of main cotter = diameter of shank × .5.

Thickness of main cotter $= \dfrac{\text{diameter of shank}}{6}$

Thickness of feathers in boss $= \dfrac{\text{diameter of boss}}{40}$

Width of small cotter $= \dfrac{\text{diameter of boss}}{20}$

Thickness of small cotter $= \dfrac{\text{width}}{2}$

Angle in side of wedge box $= 7\frac{1}{2}$ degrees.

Metal in cheeks where cotters enter =

$$\frac{\text{diameter of boss}}{40}$$

Thickness of plate over wedges $= \dfrac{\text{diameter of boss}}{48}$

Blades of screw to curve forward $\frac{1}{2}$ inch, to each foot of diameter of screw, from face at root, curve to commence at centre of blades.

The shape of the blades of this propeller is that of a pear having the ends cut off, the small end being the extremity of the blade, the larger end has cast on it a solid bearing, termed the shank, which fits into a cavity cast in the main boss, this bearing is secured by a cotter; the angle of the blade to produce the given pitch, is regulated by wedges, these are prevented from becoming loose by a plate, secured by nuts on the end of the main cotter; the blade is still further secured by bolts and nuts, passing through the flange, and a provision in the boss; the holes in the latter are a parallelogram, curved, the radii being from the centre of the boss to the centre of the bolts; the length of the holes are of course due to the angle the blade is required to assume. The following Table is taken from practice:

Dia. of Screw.	Diameter of Boss.		Length of Boss.		Lap of Blade on Boss byd. Flange.	Width of Blade at widest part.		Width of Blade at point.		Thick-ness of Blade at root.	Thick-ness of Blade at point.	Diameter of Flange of Blade.		Thick-ness of Flange of Blade.
feet.	ft.	in.	ft.	in.	inches.	ft.	in.	ft.	in.	inches.	inches.	ft.	in.	inches.
6	1	9	1	$1\frac{1}{8}$	$4\frac{1}{2}$	2	0		$10\frac{1}{4}$	2	$\frac{5}{16}$		$10\frac{1}{2}$	$\frac{1}{2}$
7	2	0	1	3	$5\frac{1}{4}$	2	4	1	0	$2\frac{5}{16}$	$\frac{3}{8}$		12	$\frac{5}{8}$
8	2	3	1	$4\frac{7}{8}$	6	2	8	1	$1\frac{3}{4}$	$2\frac{5}{8}$	$\frac{7}{16}$	1	$1\frac{1}{2}$	$\frac{11}{16}$
9	2	6	1	$6\frac{3}{4}$	$6\frac{3}{4}$	3	0	1	$3\frac{3}{8}$	3	$\frac{1}{2}$	1	3	$\frac{3}{4}$
10	2	9	1	$8\frac{5}{8}$	$7\frac{1}{2}$	3	4	1	$5\frac{1}{8}$	$3\frac{1}{4}$	$\frac{9}{16}$	1	$4\frac{1}{2}$	$\frac{13}{16}$
11	3	0	1	$10\frac{1}{2}$	$8\frac{1}{4}$	3	8	1	7	$3\frac{5}{8}$	$\frac{5}{8}$	1	6	$\frac{7}{8}$
12	3	6	2	$2\frac{1}{4}$	9	4	0	1	$8\frac{1}{2}$	4	$\frac{11}{16}$	1	9	$1\frac{1}{16}$
13	3	6	2	$2\frac{1}{4}$	$9\frac{3}{4}$	4	4	1	$10\frac{1}{4}$	$4\frac{1}{4}$	$\frac{3}{4}$	1	9	$1\frac{1}{8}$
14	4	0	2	6	$10\frac{1}{2}$	4	8	2	0	$4\frac{5}{8}$	$\frac{13}{16}$	2	0	$1\frac{3}{16}$
15	4	0	2	6	$11\frac{1}{4}$	5	0	2	$1\frac{3}{4}$	5	$\frac{7}{8}$	2	0	$1\frac{3}{16}$
16	4	3	2	$7\frac{7}{8}$	12	5	4	2	$3\frac{3}{8}$	$5\frac{1}{4}$	$\frac{15}{16}$	2	$1\frac{1}{2}$	$1\frac{1}{4}$
17	4	6	2	$9\frac{3}{4}$	$12\frac{3}{4}$	5	8	2	$5\frac{1}{8}$	$5\frac{5}{8}$	$\frac{15}{16}$	2	3	$1\frac{3}{8}$
18	5	0	3	$0\frac{1}{2}$	$13\frac{1}{2}$	6	0	2	$6\frac{7}{8}$	6	1	2	6	$1\frac{1}{2}$
19	5	0	3	$0\frac{1}{2}$	$14\frac{1}{4}$	6	4	2	$8\frac{1}{2}$	$6\frac{1}{4}$	$1\frac{1}{16}$	2	6	$1\frac{1}{2}$
20	5	6	3	$5\frac{1}{8}$	15	6	8	2	$10\frac{1}{4}$	$6\frac{5}{8}$	$1\frac{1}{16}$	2	9	$1\frac{5}{8}$
21	5	6	3	$5\frac{1}{8}$	$15\frac{3}{4}$	7	0	3	0	7	$1\frac{1}{8}$	2	9	$1\frac{5}{8}$
22	6	0	3	9	$16\frac{1}{2}$	7	4	3	$1\frac{3}{4}$	$7\frac{1}{4}$	$1\frac{1}{4}$	3	0	$1\frac{13}{16}$
23	6	0	3	9	$17\frac{1}{4}$	7	8	3	$3\frac{3}{8}$	$7\frac{5}{8}$	$1\frac{5}{16}$	3	0	$1\frac{7}{8}$
24	6	6	4	$0\frac{5}{8}$	18	8	0	3	$5\frac{1}{8}$	8	$1\frac{3}{8}$	3	3	$1\frac{15}{16}$

Dia. of Screw.	Diameter of Shank of Blade.	Metal round Shank.	Metal bet. Flange & top of Cotter.	Width of Main Cotter.	Thick-ness of Main Cotter.	Thick-ness of Feather in Boss.	Width of Small Cotter.	Thick-ness of Small Cotter.	Metal in Cheek wh. Cot. enters.	Thick-ness of Plate over Wedges.
feet.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.
6	$5\frac{1}{4}$	$\frac{7}{8}$	$1\frac{1}{4}$	$2\frac{5}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$
7	6	1	$1\frac{3}{4}$	3	1	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$
8	$6\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{15}{16}$	$3\frac{3}{8}$	$1\frac{1}{8}$	$\frac{11}{16}$	$1\frac{3}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{9}{16}$
9	$7\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{3}{16}$	$3\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{5}{8}$
10	$8\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{3}{8}$	$4\frac{1}{8}$	$1\frac{3}{8}$	$\frac{13}{16}$	$1\frac{5}{8}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{11}{16}$
11	9	$1\frac{1}{2}$	$2\frac{5}{8}$	$4\frac{1}{2}$	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{3}{4}$
12	$10\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{16}$	$5\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{16}$	$2\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$\frac{7}{8}$
13	11	$1\frac{3}{4}$	$3\frac{1}{8}$	$5\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$
14	12	2	$3\frac{1}{2}$	6	2	$1\frac{3}{16}$	$2\frac{3}{8}$	$1\frac{3}{16}$	$1\frac{3}{16}$	1
15	12	2	$3\frac{1}{2}$	6	2	$1\frac{3}{16}$	$2\frac{1}{2}$	$1\frac{3}{16}$	$1\frac{3}{16}$	1
16	$12\frac{3}{4}$	$2\frac{1}{8}$	$3\frac{15}{16}$	$6\frac{3}{8}$	$2\frac{1}{8}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{16}$
17	14	$2\frac{1}{4}$	4	$6\frac{7}{8}$	$2\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$
18	15	$2\frac{1}{2}$	$4\frac{3}{8}$	$7\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	3	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$
19	15	$2\frac{1}{2}$	$4\frac{3}{8}$	$7\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	3	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$
20	$16\frac{1}{4}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$8\frac{1}{8}$	$2\frac{13}{16}$	$1\frac{5}{8}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$
21	17	2[illegible]	$4\frac{3}{4}$	$8\frac{1}{2}$	$2\frac{7}{8}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$
22	18	3	$5\frac{1}{4}$	9	3	$1\frac{13}{16}$	$3\frac{5}{8}$	$1\frac{13}{16}$	$1\frac{13}{16}$	$1\frac{1}{2}$
23	$18\frac{1}{2}$	3	$5\frac{1}{4}$	$9\frac{1}{8}$	$3\frac{1}{16}$	$1\frac{7}{8}$	$3\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{1}{2}$
24	$19\frac{1}{4}$	$3\frac{1}{4}$	$5\frac{5}{8}$	$9\frac{5}{8}$	$3\frac{5}{16}$	$1\frac{15}{16}$	$3\frac{7}{8}$	$1\frac{15}{16}$	$1\frac{15}{16}$	$1\frac{5}{8}$

BANJO, OR LIFTING FRAME.

This frame consists of two plummer blocks to receive the propeller, with caps, connected to the upper or cross part, which is cast hollow in two parts, having within them two pulleys to lift the frame, a lever stop, and a safety catch; the latter works in perpendicular ratchets, secured to the hull of the ship on each side of the screw opening or well; the ratchet also forms a guide for the frame during the action of lifting; the use of the safety catches is, in the event of lowering the propeller, should the rope or any other part fracture, the catches are instantly allowed to act, consequently prevent the fall of the propeller and frame. The use of the lever stop is to prevent the propeller from deviating from the perpendicular line during its ascent, also when it is not required, or the ship under sail. For small engines, up to 200 HP collectively, the plummer block cap is connected to the cross part by a rod keyed on a bush, cast on each cap. For engines above this power, the cap and cross part are in one casting, the connecting part being hollow in section as a box girder, open at the part facing the ratchet. The cross part for small engines, is usually ribbed between the provision for the levers, stop, and safety catches, the attachment of the rope or chain to the frame being to a ring, secured to the frame by a pin, the position of which should be so that during the process of

lifting, the weight will be equally distributed, thus ensuring a free ascent.

Frame for Small Engines.

Diameter of lifting ring pin $= 1\frac{1}{4}$ inch as a minimum for a screw 4 feet in diameter, increasing in diameter from this $\frac{3}{16}$ of an inch per foot of screw's diameter.

Thickness of sides and top of cross part of frame (the lower part being open) $= \frac{3}{8}$ to $\frac{1}{2}$ an inch.

Width of ends and sides = width of **T** coupling.

Area of lifting ring = area of lifting pin $\times .5$.

Diameter of stay rods, connecting cross part of frame to cap of bearing block = diameter of lifting ring pin.

Depth of ends of cross part = width $\times 2$.

Depth at centre = depth at end $\times 1.75$ to 1.5.

Diameter of boss on caps = rod's diameter $\times 1.6$.

Depth of keys = rod's diameter.

$$\text{Thickness of keys} = \frac{\text{rod's diameter}}{4}$$

Thickness of brass of cap and bottom =

$$\frac{\text{diameter of bearing of screw}}{5 \text{ to } 7}$$

Area of bolts in one cap (4) = area of lifting pin $\times 1.5$ to 1.3.

Depth of bosses = diameter of bolt $\times 1.5$.

Length of bearing = diameter of bearing $\times 1$ to $.8$.

BRASS FRAME FOR LARGE ENGINES ABOVE 200 HP COLLECTIVELY

This class of frame and cap, as before stated, is in one casting.

Diameter of lifting pin = 3 inches for engines 200 HP collectively, having an increase of $\frac{3}{8}$ of an inch per foot of diameter of screw above 14 feet.

Thickness of body of frame = $\frac{1}{2}$ to $\frac{7}{8}$ of an inch.

Width of sides of frame = width of T coupling of screw propeller.

Depth of cross part, midway from centre, to sides = width of sides × 2.25.

Depth at centre = width of side × 3.

Diameter of rope pulley at bottom of groove = one inch per foot of screw's diameter.

Thickness of body = $\frac{1}{4}$ to $\frac{5}{8}$ of an inch.

Diameter of boss = diameter of pin × 1.5.

Width of groove = diameter of lifting pin.

Diameter of pin screw for stop lever = diameter of lifting pin × .6 to .5.

Diameter of screw for adjusting stop lever = diameter of lifting pin × .7 to .6.

Depth of stop lever at centre = diameter of lifting pin × 2 to 1.75.

Thickness of stop lever = depth × .5 to .4.

Depth of stop lever at boss and clutch = depth at centre × .5.

Diameter of catch pin = diameter of lifting pin × .7 to .6.

Diameter of boss for catch pin = diameter of pin × 2.

Taper of catch = 2 inches per foot.

Thickness of catch at point = depth at point.

Thickness of bottom of bearing block and cap =

$$\frac{\text{diameter of bearing}}{4 \text{ to } 5}$$

When strips of lignum vitæ are used, there should be a separate tube (in halves) inserted in the blocks, with provisions for fitting and securing the wood and tube.

Thickness of tube = $\frac{1}{4}$ to $\frac{1}{2}$ inch.

Thickness of each strip of lignum vitæ = $\frac{1}{2}$ inch as a minimum, $1\frac{1}{4}$ as a maximum.

Width of strips = thickness × 3 to 2.5.

Thickness of metal between strips = thickness of tube × 1.6 to 1.5.

Total area of bolts in one cap (4) = area of lifting pin × 1.35 to 1.2.

STERN BRACKET.

Thickness of metal = that for lifting frame × 1.25.

Diameter of securing bolts = thickness of metal × 1.25.

Proportion of lignum vitæ strips as before.

Pitch of safety ratchet = $2\frac{1}{2}$ to 4 inches.

The means on deck for lifting the propeller and frame is by a capstan, shear legs, and rope

or chain. The screw frame, when lowered, is retained in its position rigidly by a piece of wood, resting in cavities cast or secured on the frame; this piece of wood is from 5 to 10 inches square, the top part being secured by a screw or wedge; the former being the better mode.

OSCILLATING ENGINES.

The use of these engines for marine purposes has been proved to be applicable for the paddle wheel, but the excessive friction (caused by the vibration of the cylinder) on the piston rod, also that of the trunnions, render it necessary that the piston rod and crank shaft have larger proportions, than for engines adapted for the screw. To equalize the motion of the oscillating engine on either side of the centre line, the slide valves and casings are two in number, one on each side of the cylinder; the valves are worked by levers hung on pins secured to the cylinder; one end of each lever is attached to its respective slide valve, and the other ends are secured to sliding blocks, which work in a shifting quadrant. By this arrangement the motion of the slides, derived from the eccentrics and the crank shaft, are very little (if scarcely) affected by the motion of the cylinder; in some cases the slide valves are worked by a single eccentric to each cylinder; the eccentric being loose on the crank shaft, assumes its proper angle

for astern, or ahead, by a catch or stud, secured in the crank shaft; the catch works in a channel in the boss of the eccentric for a given length of arc; a counter-balance is secured to the eccentric so as to cause the same to be on the perpendicular line, when its rod is released. A better plan for working the slide valves is the locomotive valve link motion, already described for engines adapted for the screw, although the action of the doubl eccentrics, when the link is introduced, is not so sudden as that of the single; but the means for ensuring accuracy of the stroke of the valve, on reversing the engines, is reliable by the adoption of the link; it is practically essential to secure the engines as near the keel of the ship as possible; the angle of the piston rod should never exceed 70°. The following rules will produce the practical results of the present day:

NOMINAL HP.

The following Table will enable the area of the cylinder to be easily obtained:

HP for one cylinder.	Number of square inches per HP.	
20 to 80	= 33 to 24	when the stroke = the diameter of the cylinder.
90 " 150	= 23.8 " 22	
180 " 300	= 21.87 " 20	
350 " 500	= 19.87 " 19	

The area to be increased or decreased in proportion to the stroke.

LENGTH OF STROKE.

The stroke of the engine is due to the depth of the ship, displacement, etc.; the usual proportions to the diameter of the cylinder = diameter of cylinder × .8 to 1.

THICKNESS OF THE METAL OF CYLINDERS.

HP collectively.	Diameter of each Cylinder. in.	Length of Stroke. ft. in.	Thickness of Metal.	
40	29	2 6	$\frac{5}{8}$	including for re-boring
100	$40\frac{3}{4}$	3 6	$\frac{7}{8}$	
150	$48\frac{3}{8}$	4 0	1	
200	$54\frac{1}{2}$	4 6	$1\frac{1}{8}$	
300	$61\frac{7}{8}$	5 0	$1\frac{1}{4}$	
400	$74\frac{1}{4}$	6 0	$1\frac{3}{8}$	
500	$81\frac{7}{8}$	6 6	$1\frac{7}{16}$	
600	$87\frac{1}{2}$	7 0	$1\frac{1}{2}$	
800	100	8 0	$1\frac{5}{8}$	
1000	110	9 0	$1\frac{3}{4}$	

Area of steam port supply = HP × 1. to .75.

Length of steam port = diameter of cylinder × .6 to .4.

Diameter of valve lever pin = diameter of slide rod × 2.

The remaining proportions for steam ports, slide valve, casing, rods, eccentrics, links, and pins, are as for screw engines.

PISTON ROD.

Approximate length = stroke × 1.75.

Diameter of piston rod $= \dfrac{\text{diameter of cylinder}}{8 \text{ to } 10}$ using the latter in large cylinders and short strokes.

Total area of cap bolts (2) = area of piston rod × .5.

Thickness of cap and head = diameter of bolt.

Diameter of cap socket = diameter of piston rod at socket × 1.5.

Thickness of brasses $= \dfrac{\text{diameter of crank pin}}{6 \text{ to } 8}$

Depth of key = diameter of piston rod × 1 to .75.

Thickness of key $= \dfrac{\text{diameter of piston rod}}{4}$

Diameter of stuffing box of piston rod = diameter of rod × 1.5.

Depth of stuffing box = diameter of rod.

Depth of bush = diameter of rod × 2.5 to 2.

Thickness of bush = $\frac{1}{4}$ of an inch as a minimum, increasing $\frac{1}{16}$ of an inch per 3 inches of rod's diameter.

Depth of gland = depth of stuffing box × .4 to .5.

Thickness of metal of stuffing box = thickness of gland.

Diameter of oil cup = diameter of gland.

Depth of oil cup = thickness of gland × 2.

The remaining proportions of the covers, man

hole, piston, studs, and bolts, etc., are as for screw engines.

Trunnions and Steam Passages.

Area of steam passage = area of one exhaust port.

Width of steam passage = width of one exhaust port.

Length of passage $= \dfrac{\text{area}}{\text{width}}$

Thickness of metal of passage = thickness of body of cylinder.

Area of steam opening in trunnion = area of one exhaust port × 2 as a minimum.

The steam pipe is often of gun metal $\frac{1}{8}$ to $\frac{3}{8}$ of an inch in thickness.

Length of bearing of trunnion = diameter of valve steam opening × .5.

Thickness of gland = $\frac{1}{2}$ inch as a minimum for a pipe 6 inches in diameter, increasing $\frac{1}{2}$ inch per 6 inches of diameter of pipe.

Thickness of metal of trunnion at neck = thickness of cylinder × 3 to 2.5.

Thickness of trunnion of stuffing box = thickness at neck × .7 to .5.

Thickness of flange of trunnion = thickness at stuffing box × 1 to .75.

Depth of stuffing box = diameter of steam pipe × .6 to .4.

Depth of gland $= \dfrac{\text{depth of stuffing box}}{3}$

Diameter of gland studs = ⅝ to 1¼ inch.

Pitch of studs in gland and flange of pipe = diameter of studs × 7 to 10.

Thickness of brasses for trunnions = thickness of stuffing box × .8 to .6.

Thickness of cap (cast iron) =

$$\frac{\text{diameter of trunnion}}{3 \text{ to } 5}$$

Thickness of cap (wrought iron) =

$$\frac{\text{diameter of bearing}}{6 \text{ to } 8}$$

Total area of cap bolts (2) = area of piston rod × .6 to .5.

Diameter of securing bolts = diameter of cap bolts.

Thickness of metal under trunnion brasses = thickness of cast iron cap.

Condenser.

Cubical contents of condenser for two cylinders =

$$\frac{\text{cubic contents of one cylinder} \times 1.5}{6 \text{ to } 7}$$

Air Pump Vertical Action.

Cubical contents of air pump, single acting, when one is used = that of condenser.

Cubical contents of one air pump, single acting, when two are used =

$$\frac{\text{cubical contents of one cylinder}}{6 \text{ to } 7}$$

Stroke of air pump = stroke of engine × .5 to .4.

Area of suction valves in piston = effective area of pump × .3 to .25, or as much larger as practical.

Diameter of connecting rod =

$$\frac{\text{diameter of air pump}}{7 \text{ to } 9}$$

Diameter of pin for piston = diameter of connecting rod.

Thickness of trunk at neck = $\frac{1}{4}$ to $\frac{3}{8}$ of an inch, slightly tapering at the extremity.

Depth of stuffing box for trunk $= \dfrac{\text{diam. of trunk}}{4. \text{ to } 5.}$

Depth of gland = depth of stuffing box × .6 to .7.

Thickness of gland $= \dfrac{\text{diameter of trunk}}{8 \text{ to } 10}$

Area of one cap bolt = area of connecting rod × .25.

Thickness of keying socket $= \dfrac{\text{diameter of rod}}{3}$

Crank Shaft.

Diameter = diameter of piston rod × 1.8 to 1.6.

Length of bearing = diameter of bearing × 2.

Crank Pin.

Area = area of piston rod × 1.5 to 1.4.
Length of bearing = diameter × 1.5.

Cranks.

Depth of shaft's eye = shaft's diameter.
Depth of pin's eye = diameter of pin.
Extreme diameter of eye = diameter of hole × 1.66.
Sectional area of each web of crank = area of bearing × .75.

Disengaging Gear.

The usual mode adopted by engineers, for disengaging the paddle shaft from that of the engine is by a disc, surrounded by a ring connected to the crank pin, which ring is rendered stationary on the disc by a key, between the disc and crank pin; this mode is cumbersome, and the liability of the ring to expand by the action of the key, tends to throw undue strain on the crank pin. The author therefore advises that the crank pin and shaft be connected by a strap and key similar to that of connecting rods; by this means the strain from the shaft to the crank pin will be permanent.

Lower Frame.

The use of this frame is to secure the trunnion plummer block of the cylinder, the frame being connected to the condenser by studs or bolts.

Thickness of metal of frame = 1 to $1\frac{1}{2}$ inch.
Depth of frame is not imperative, but a good rule is piston rod's diameter × 2.
Diameter of securing studs = thickness of metal.

Entablature.

Total area of cap bolts (2) = piston rod area × .7 to .6.
Thickness of cap (wrought iron) = diameter of securing bolt.
Thickness of cap (cast iron) = diameter of securing bolt × 1.5.

$$\text{Thickness of brass} = \frac{\text{diameter of crank shaft}}{8 \text{ to } 10}$$

Thickness of metal of body = $\frac{3}{4}$ to $1\frac{1}{2}$ inch.
Thickness of solid sides of frame = that of the body × 2.
Diameter of flange bolts = $1\frac{1}{4}$ to 2 inches.
Thickness of flange = thickness of body × 1.3.
Depth of solid sides = diameter of bearing × 1.25.
Depth of frame beyond brass of bearing = diameter of bearing × 1.5.
Thickness of metal under brass = that of solid sides × 2 to 1.5.

Area of each supporting stay rod (2 to each bearing of crank shaft) = area of piston rod × .4 to .3.

The entablature is adjusted by screwed keys, or wedges and nuts; when cast iron cross stays are used, the area of the stay rods may be slightly decreased. The remaining proportions for the oscillating engines are as for screw engines.

Paddle Wheels.

The propulsion of ships, by this means, is the same in principle as the common boat-oar used by hand. The proportions of the floats of paddle wheels are of course due to the displacement of the vessel. The following rules are compiled from practical results and may therefore be relied on:

$$\text{Immersion of floats to centre} = \frac{\text{draft of vessel}}{2 \text{ to } 3}$$

Use the former for shallow, and the latter for deep drafts.

Two to 2½ floats should be immersed for river steamers, and 4 to 5 for sea-going ships.

Diameter of paddle at centre of floats = depth of immersion to centre of floats × 5 to 7, using the latter for high speeds and shallow drafts.

Width of float = depth of immersion to centre of float × 1 to .75, using the latter for river steamers and shallow drafts.

Pitch of floats = 2 to 1.5 of the width, but the number determined on to be immersed will be the best principle to ascertain the pitch.

Nominal HP requisite for each paddle wheel = total area in feet of the floats immersed × 1.3 to 2. Use the latter for sea ships.

The area of each float = area of longitudinal immersed section of wheel, to pitch line of float × .7 to .8, using the latter for deep immersions.

$$\text{Length of each float} = \frac{\text{area}}{\text{width}}$$

Details of Feathering Paddle Wheel.

$$\text{Dia. of arm centre} = \frac{\text{diameter of pitch line}}{3.5 \text{ to } 4}$$

$$\text{Thickness of metal of boss} = \frac{\text{diameter of shaft}}{4 \text{ to } 5}$$

Length of boss = diameter of shaft × 2.

Diameter of eccentric shaft = diameter of crank shaft × .6 to .4.

Thickness of bushes = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Area of lever shaft = 1 square inch per 5 to 7 square feet of float, using the latter for narrow floats.

Area of lever pin = area of lever shaft × .7 to .8.

Diameter of radius rods = diameter of lever pins.

Thickness of metal of eccentric = $\frac{1}{2}$ of pin's diameter.

Diameter of boss of eccentric shaft bracket = diameter of eccentric shaft × 2.

Width of paddle wheel rings = diameter of lever shaft as a minimum.

Thickness of rings = width × .3.

Position of rings from ends of floats =

$$\frac{\text{length of float}}{4}$$

Starting Gear for Screw and Paddle Engines.

Marine engineers seem to have a diversity of opinion, as to the mode and proper position of this gear. Usually the starting wheel has from 6 to 8 handles, equidistant on the periphery of the rim; the wheel is keyed on the end of a shaft having a worm at its opposite extremity, which worm gives motion to a toothed segment, keyed on a weigh shaft centrally, at each end of which are levers, connected by a rod to the slide valve link; this is very powerful, and universally adopted. The next arrangement of gear is a wheel and-shaft as above, having keyed on the weigh shaft a spur pinion, which imparts motion to a spur segment; this motion being conveyed to the link as before stated. This last arrangement is certainly of a more simple character than the former, but the spur gear necessitates a friction stop on the hand wheel shaft, to prevent the latter from turning during the motion of the engines. The next, and most modern arrangement, is a mitre wheel keyed on the starting

wheel shaft; the former gears with another on the end of a rod, having a coarsely pitched screw chased on it; the screw works in the boss of the last mitre wheel, which revolves on the hand wheel giving motion to it, consequently causing the ascent or descent of the screw rod, which is connected to the valve link in the usual manner; in some cases the link rod is connected to a sliding block, which receives motion from the screw; the rod revolving thus gives motion to the link. These two latter arrangements are generally adopted for engines above 300 HP collectively, the two former being for engines of all classes and power.

POSITION.

The position of the starting wheel by many makers is on the top of the condenser, the wheel shaft being geared with the weigh shaft of the spur segment; this latter shaft revolves in provisions secured either to the main frames or the cylinders. This arrangement (should the starting gear be disabled by shot when in action or otherwise) entails danger and great practical difficulty in stopping or reversing the engines. To Messrs. Humphrey and Tennant is due the origin of placing the starting wheel at the side, instead of the top of the condenser, which of course prevents the exposure the usual plan is liable to. The author therefore recommends that the start-

ing wheel both for screw and oscillating engines, should be as near the bottom of the ship as possible.

The following rules for starting gear are deduced from practice:

Diameter of wheel at centre of handles = 2 feet 6 to 3 feet 6 inches.

Height of centre of handles from starting platform = 3 feet 6 inches.

Length of handles = $4\frac{1}{2}$ to 6 inches.

Diameter of handles at neck = 1 inch.

Diameter of handles at extremity = $1\frac{1}{4}$ to $1\frac{3}{8}$ of an inch.

Diameter of bosses for handles = diameter of handles at neck × 2.

Thickness of rim of wheel = diameter of handle bosses.

Depth of rim = thickness of rim × .75.

Width of arm at rim = depth of rim.

Taper of arm $\frac{1}{4}$ inch per foot.

Diameter of wheel shaft = diameter of slide valve rod.

Diameter of boss for shaft = diameter of shaft × 2.

Diameter of weigh shaft of spur segment = diameter of wheel shaft × 1.25.

When two starting wheels are used, the area of each shaft = the area for 1 wheel × .75.

Ratio of pinion or worm to segment = 4 or 6 to 1.

Pitch of teeth in inches = diameter of slide valve rod × .8 to .5, using the latter for the greater ratio.

Pitch of teeth of mitre wheels (gun metal) = diameter of valve rod × .4 to .3.

Diameter of screw rod = diameter of slide valve rod × 1.4 to 1.25.

Width of sliding block = diameter of screw rod × 1.5.

Length of sliding block = diameter of screw rod × 2.

Pitch of screw = diameter of screw.

Diameter or area of link connecting rod = that of valve rod.

Diameter of lever weigh shaft = diameter of slide valve rod × 1.5 to 2.

Turning gear for paddle engines is generally a toothed ring of wrought iron, secured to the outer ring nearest the side of ship; this toothed ring is set in motion by a pinion keyed on a shaft, the latter being worked by a handle on the main deck.

Pitch of teeth 1 to 2½ inches.
Diameter of pinion shaft = pitch of teeth.

VALVES.

KINGSTON VALVES.

This valve is used to allow the sea water to flow into the condenser, bilge, or boilers.

Diameter of valve $= 2\frac{1}{2}$ to 9 inches, but from 4 to 6 inches is the most practical to keep water-tight, and secure to the bottom of the ship.

Depth of valve $= \dfrac{\text{diameter}}{2 \text{ to } 3}$

Thickness of valve $= \dfrac{\text{diameter}}{6 \text{ to } 8}$

Diameter of valve-guide's spindle $= \dfrac{\text{diameter of valve}}{5 \text{ to } 7}$

Taper of side of cone inserted in ship $= 2$ to 3 in 12.

Position of guard $=$ length of cone beyond valve $\times .5$.

Depth of guard $=$ depth of valve.

Length of guide of valve spindle should allow the valve to open $\frac{1}{4}$ of the valve's diameter.

Thickness of guard $= \frac{1}{8}$ as a minimum for guards 3 inches in diameter, increasing, above this, $\frac{1}{8}$ of an inch per 2 inches of diameter.

Diameter of valve rod $= \frac{1}{4}$ to $\frac{3}{16}$ of an inch per inch of valve's diameter.

Thickness of body of Kingston $= \frac{3}{8}$ as a minimum for $2\frac{1}{2}$ inches in diameter, increasing, above this, $\frac{1}{8}$ to $\frac{1}{16}$ of an inch per inch of diameter.

Diameter of clip studs $=$ diameter of valve rod $\times .75$.

Depth of clip $=$ diameter of valve rod $\times 1$ to $.75$.

Length of handle 6 to 10 inches.

Diameter of handle 1 to $1\frac{1}{4}$ inch.

The proportions for the stuffing box, gland, studs, and flange, are as those for the engine.

CYLINDER RELIEF VALVE.

The use of this valve is to allow the egress of the condensed steam or water, from the cylinders when requisite, in the case of an inundation in the latter, either from the priming of the boilers or starting of the engines; the spring of this valve is either released, to allow a free exit from the cylinder, or by a cock between the cylinder and the under side of the valve; the latter seems to be preferable, and is universally adopted. The author has devised a relief valve which dispenses with the cock and yet retains its practical value, by the following arrangement. The spring valve is perforated to receive an India-rubber disc valve on its outside; on the inside a provision is cast, and turned to receive a common solid brass disc valve, which, on being pressed inwards, allows free exit for the steam and water, and on a vacuum being in the cylinder, the India-rubber diso valve closes, and covers the perforations air tight; on the return action of the piston, the India-rubber valve again opens; on closing the solid brass valve, the perforations are rendered non-effective, and the spring valve becomes a solid disc valve, of the usual kind, but dispensing with the cock or releasing screw as before alluded to. This improve-

ment is fully shown in the author's practical illustrations.

Area of relief valve for each end of cylinder = one square inch per square foot of area of cylinder.

Diameter of spring should be as large as the valve will admit of, for valves 4 inches in diameter; beyond this, the diameter of the spring = diameter of valve × .8 to .75.

Sectional area of each coil of spring = .25 of a square inch per 3 inches of the spring's diameter; this of course depends on the pressure of the steam, the present rule being for a pressure of 20 lbs. per square inch.

Number of coils 4 to 6.

Space between coils = diameter or side of square of coils × 1.3 to 1.

$$\text{Thickness of valve} = \frac{\text{diameter of valve}}{6 \text{ to } 8}$$

$$\text{Diameter of valve spindle} = \frac{\text{diameter of valve}}{5 \text{ to } 7}$$

Expansion Valve.

In cases where steam is used expansively, a valve has to be introduced, between the slide and throttle valves, thus regulating the steam, or cutting it off, at a given portion of the stroke of the piston. Makers of marine engines, as a rule, with an exception or two, have different ideas as to the proper kind of expansion valve, and mode of

working the same. The following will be a statistic of those worthy of notice:

First, the old variable cam, correct in principle and action, with the common throttle or slide valve; secondly, the eccentric, as a medium to obtain motion, with its grid-iron or cross-barred valve, common slide valves, single and double beat valves, sliding circular port valve, with its slotted adjusting lever, pins, etc.; thirdly, spur and mitre gearing, deriving its motion of course from the crank shaft, with square, round and oval valves, also revolving circular ported valves.

The correct principle to be adhered to, in the expansion valves is, that friction should be dispensed with as much as possible, so that the action be not impeded; consequently the lesser the amount of mechanical means introduced to gain the action of the valve the better; spur and mitre gearing involve a great amount of friction, but direct in action; the eccentric motion is uncertain, unless the valve be neutral during a portion of the stroke; this last is fully illustrated in the author's Practical Illustrations.

The cam motion is undoubtedly the best when the common slide, throttle, or double beat valves be used. The proper lead for the slide valve is dubious, but practice teaches $\frac{1}{16}$ to $\frac{3}{16}$ of an inch, using the latter for high speeds. The points for cutting off for expansion are various, six points or grades during the travel of the piston being

available, but the chief guide is the pressure of the steam, as the higher or greater the pressure, the more the powers of expansion. In some cases cylinders have a steam space or jacket, which is a belt cast around the whole length of the cylinder from the sides of the valve facing and steam passages; within this space steam is admitted, exhausting into the expansion valve casing or casings, as the case may be; this retains the heat of the cylinder, which produces a greater expansion; in some cases the steam is exhausted into the jacket and thence to the condenser. Although this distribution of the steam may be correct in theory, in practice, with a moderate pressure, the gain in power, speed of ship, and reduction in the consumption of fuel, is not so startling as might be expected, and unless high pressure steam be used, say 45 to 50 lbs. per square inch, the expansive power will not produce a saving of fuel, accompanied by power, worthy of attention and productive of economy.

Surface Condensation.

This mode of condensing is by the contact of the steam with a surface of metal, either flat or curved, the latter being universally used in the shape of tubes; a continuous stream of cold water passing through them, retains the constant cooling powers by which the steam is condensed;

copper, muntz, or gun metal are the best conductors of heat and cold. The arrangement of the tubes and modes for circulating the water is various. Many makers prefer the tubes fixed horizontally in sets over each other, having the water circulated through the lower set, after which through the higher or top set. This arrangement is compact and effective; the water is forced through the tubes by a common pump, either single or double acting, a good arrangement being to drain the condensed steam at one end, and force the circulating water at the other; thus one pump is sufficient for the duty required. In some cases a double acting pump is used to drain the condenser, and the circulating water is forced or drained by a centrifugal pump; this entails a separate engine to drive the same, as a high velocity has to be continuously maintained. In some cases the tubes are vertical. The following proportions for the cooling surface, cubic contents of pump, and area of valves, will be found practically correct, being deduced from the best results yet attained:

Area of cooling surface of tubes $=$ HP $\times$ 12 to 7, the former being a maximum for 100 HP, and the latter a minimum for 1000 HP.

Cubical contents of air pump, single acting $=$

$$\frac{\text{cubical contents of cylinder}}{12 \text{ to } 15}$$

Area of valves for circulating water = area of pump × 1.3 to 1.25.

Area of valves for condensing steam = area of pump × .6 to .5.

External diameter of tubes is usually one inch.

Thickness of tube $\frac{1}{8}$ of an inch.

Length of tube 7 feet as a maximum.

Thickness of tube plate = diameter of tube.

The number in one plate = 1000 tubes as a maximum.

The plate should be stayed every square foot as near as practice will admit of.

The modes of rendering the tubes air-tight when secured in the plate, but at the same time capable of being readily removed, are multitudinous; the best mode for securing horizontal tubes is by a ring of India-rubber to each tube, the latter protrudes from the plate $\frac{3}{4}$ to $1\frac{1}{4}$ inch, the rings fit in the recesses which are cast around each tube, on the outer side of the plate, and on a vacuum being caused in the condenser, the India-rubber rings render the tube joints air-tight, whilst the increased length of the tubes allow a free expansion of material. In perpendicular tubes, the upper and lower ends are secured with a nut and India-rubber ring, whilst the expansion is effected by the elasticity of the ring.

EXHAUST WATER VALVE.

This valve is secured to the side of the ship below or at the load water line; the valve is a disc of gun metal, with 3 ribs, or a spindle as a guide, the means of raising the valve is by a rope and pulley, or block secured to the coal bunker plates, or deck of ship, this being preferred to a screw, being more instantaneous in its action for raising or lowering the valve. The body of the casing has cast on its lower end, or that at right angles with the secured part, a stuffing box, to allow for the expansion of the exhaust water pipe.

Internal area of casing = area of extreme diameter of valve × 2.

Thickness of casing gun metal = $\frac{3}{8}$ of an inch for casing 12 inches in diameter, increasing $\frac{1}{4}$ of an inch per 6 inches of diameter.

Thickness of casing (cast iron) = thickness of that for gun metal × 2 to 1.75.

$$\text{Thickness of valve} = \frac{\text{diameter of valve}}{10 \text{ to } 15}$$

$$\text{Diameter of valve spindle} = \frac{\text{diameter of valve}}{8 \text{ to } 12}$$

Proportion of the stuffing box, gland, cover, flanges, and studs, as for steam cylinder.

DONKEY ENGINE.

This engine is, to the engineer, what a reserved number of soldiers is to a general of an army;

in both cases each is only required in a case of emergency. The arrangements of a donkey engine is usually a cylinder, secured perpendicularly over the pumps, having a slotted cross head, to give motion to the crank shaft and fly wheel; the use of the latter is to assist the action of the plunger; each side of the cross head is keyed or bolted to the rods of the cylinder and pump, the steam cylinder is supplied with steam from the boilers, and either exhausts into the condenser or funnel.

Cubic contents of the pump = cubic contents of feed pump for one engine as before deduced × 1.5.

Stroke of pump = diameter × 1.25.

The remaining proportions of the pump and valves are as for that of the engine.

Area of steam cylinder = area of pump × 1.5.

The remaining proportions of the engine are as for high pressure engines.

LAND AND MARINE BOILERS.

Land Boilers.

The best kind of boiler is that known as the Cornish or flue boiler. The following tables and rules will enable the practical proportions to be easily obtained:

Nom. HP.	Number of Square Feet of Heating Surface per HP.	Divisor.	Length.		Diameter of Boiler.		Diameter of Tube.	
			ft.	in.	ft.	in.	ft.	in.
10	12.375	7.22	17	0	4	3	2	$1\frac{1}{2}$
12	12.3	7.97	18	6	4	6	2	3
15	11.96	8.97	20	0	5	0	2	6
20	11.3	9.493	23	6	5	6	2	9
25	10.98	10.32	26	6	6	0	3	0
30	10.27	10.83	28	6	6	3	3	$1\frac{1}{2}$

$$\text{Length of boiler} = \frac{\text{Total heating surface of boiler}}{\text{divisor as per table}}$$

$$\text{Diameter of boiler} = \frac{\text{length}}{4 \text{ to } 4.5}$$

$$\text{Diameter of single tube} = \frac{\text{diameter of boiler}}{2}$$

$$\text{Depth of water line from top of boiler} = \frac{\text{diameter of boiler}}{3}$$

$$\text{Height of water line from top of tube} = \frac{\text{diameter of boiler}}{12}$$

When two tubes are used in the boiler, their position from top of boiler must be as for a single tube.

Diametrical length of flues = diameter of tube.

Heating surface of tubes = total surface of tube = .5.

Heating surface of bottom flue = total surface of boiler exposed in flue.

Heating surface of side flues = surface of boiler exposed in both side flues × .5.

Grate or fire bar surface = 1 to ¾ of a square foot per HP.

$$\text{Area of side flues} = \frac{\text{area of grate surface}}{4}$$

Area of bottom flue = area of side flue.

Width of bottom flue = diameter of tube.

$$\text{Width of side flue} = \frac{\text{area}}{\text{length}}$$

$$\text{Length of fire bar of grate} = \frac{\text{area of grate surface}}{\text{diameter of flue}}$$

Height of bridge = ⅞ of diameter of flue.

Area of safety valve = 1 to .75 square inch per HP of boiler.

$$\text{Length of lever} = \frac{\text{diameter of boiler}}{3}$$

Weight in lbs. on end of lever =

$$\frac{\text{pressure against the valve in lbs.} \times \text{by distance from centre of valve to centre of suspension}}{\text{distance from centre of suspension to centre of weight}}$$

Pressure on valve in lbs. =

$$\frac{\text{weight in lbs. on end of lever} \times \text{length of lever from centre of suspension to centre of weight}}{\text{distance from centre of valve to centre of suspension}}$$

Distance from centre of suspension to centre of

$$\text{valve} = \frac{\text{length of lever}}{9 \text{ to } 10}$$

Pressure in lbs. per square inch $= \dfrac{\text{pressure in lbs. on or against the valve}}{\text{area of the valve in square inches}}$

Pressure on or against the valve in lbs. = pressure per square inch × area of valve in square inches.

Marine Boilers.

The best class of marine boilers is undoubtedly the multitubular, having the tubes longitudinally over the valve box. In cases where shallow drafts are imperative, and the top of the boiler must be below the load water line of the vessel, the tubes are on a level with the fire boxes at right angles.

Total heating surface of the tubes = HP × 12 to 10 as a minimum, for boilers above 200 HP; HP × 14 to 16 as a maximum below 150 HP.

Diameter of tubes externally = 2 to 3 inches.

Length of tubes = 5 to 7 feet.

Number of tubes $= \dfrac{\text{total surface}}{\text{surface of one tube}}$

Rake or inclination of tubes = $\frac{5}{8}$ to $\frac{3}{4}$ of an inch per foot.

Water space = 4 to 6 inches.

Diameter of stays = 1 to $1\frac{1}{4}$ inch.

Position of stays at right angles above fire boxes = 14 to 16 inches.

Position of stays at sides and bottom of fire boxes = 12 to 14 inches.

These rules for stays are for a pressure of 20 lbs. per square inch on the total surface of boiler.

Number of tubes to one fire box should never exceed 125.

Width of fire box at tube = pitch of tubes × number of tubes transversely.

Fire bar or grate surface = HP × .75 to .5, using the latter for boilers above 150 HP.

Length of fire bar grate surface = 7 feet as a maximum, 5 to 6 feet being generally adopted.

Width of fire box at grate =

$$\frac{\text{surface of grate}}{\text{length of grate surface}}$$

Radius for top and bottom curves of fire box = width of fire box.

Radii of small curves $= \dfrac{\text{width of fire box}}{4 \text{ to } 5}$

Width of fire door opening 18 inches as a minimum; above this width the fire door opening = width of fire box × .875.

Area of fire box at grate = grate surface × .5.

Area of space above bridge =

$$\frac{\text{area of grate surface}}{4}$$

Cubic contents (in feet) of steam capacity = HP × 2 as a minimum, and HP × 4 as a maximum.

Height of water line above fire box at tube end = 6 to 8 inches.

Width of fire box at back end = 18 inches; this

will allow room for closing or riveting the end of the tubes when renewed.

Width of smoke box at bottom = 14 inches as a minimum.

Area of opening in uptake = total area of tubes as a minimum; total area of tubes $\times$ 1.25 as a maximum.

$$\text{Area of chimney} = \frac{\text{total area of grate surface}}{8 \text{ to } 11}$$

In war ships the following should be observed:

Top of boiler should be one foot below water line as a minimum; funnel to be telescopic, raised and lowered by two chains on a barrel, keyed on a shaft, to which motion is given by a worm and wheel on each side of the funnel.

Diameter of shaft = 2 to $3\frac{1}{2}$ inches.
Diameter of wheel = 18 to 24 inches.
Pitch of teeth = $1\frac{1}{2}$ to 2 inches.

$$\text{Diameter of worm} = \frac{\text{diameter of wheel}}{4}$$

Radius of handle = 14 inches.

In order to reduce the temperature between deck and the stoke hole, the funnel is surrounded by 2 casings, 4 to 6 inches of space between each, commencing on the main or weather deck, and terminating on the orlop or lower deck; by this means a continuous current of air passes through. The stoke hole is further ventilated, and draught increased in some cases by tubes, the tops of

which are termed cowls, from being enclosed semicircularly, having the opening at the side, the top being rotative, and its position subservient to the wind.

Safety Valves.

These valves are two to each boiler in one casing, as the action of the sea causes the ship to pitch or roll; consequently levers with weights are entirely dispensed with, the weight being either directly over or under the valve.

Area of valve in square inches =

$$\frac{\text{total area of grate's surface in feet}}{3}$$

Diameter of valve spindle $= \dfrac{\text{diameter of valve}}{4}$

Diameter of weight = diameter of valve × 2.

Pressure in lbs. against the valve = pressure per square inch × area of the valve.

Cubical contents of weight, including weight of valve and spindle =

$$\frac{\text{pressure in lbs. against the valve}}{.263}$$

Length of weight $= \dfrac{\text{cubic contents of weight}}{\text{area of weight}}$

Thickness of casing = $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

Depth of guide ribs of valve = diameter of valve × .5.

Diameter of lifting lower weigh shaft = diameter of valve spindle.

Length of lifting lever = diameter of weight + ½ inch for clearance between weight.

$$\text{Lift of valves} = \frac{\text{diameter of valve}}{4}$$

Diameter of surface blow off pipe = 2 to 4 inches.
Diameter of bottom blow out pipe = 3 to 5 inches.

Between each fire box, above and below, there should be openings for the purpose of cleansing the crown of furnaces or fire box and bottom of boilers; these openings should be rendered tight by doors, secured by bolts and nuts.

SUPERHEATING

This is an arrangement of tubes surrounded by steam, and filled with the flame, smoke, and heated gases from the boiler tubes, thus heating or drying the steam; by this means a greater amount of expansion and purity of steam is obtained. The best arrangement in practice at present is a series of tubes vertically secured in plates in the uptake, but in the case of a fracture in any of the superheating tubes, the damper is so arranged that the exit from the boiler tubes can be effected through the opening, without passing through the tubes; a set of valves and pipes are arranged to enable the steam, if required, to pass from the boiler to the engine without being superheated.

Total surface of tubes in square feet, minimum = $HP \times 3$, maximum = $HP \times 5$.

Diameter of tubes internally $= 1\frac{3}{4}$ to 4 inches.
The latter is the best for a quick draught, and the more readily cleansed.

Thickness of tubes, wrought iron $= \frac{1}{4}$ of an inch.

Length of tubes are as their position requires.

Each boiler should be fitted with a gauge glass, surface blow off, blow out, supply sea, and feed water cocks, tubes, ash box, cleansing doors; the admission of air by the ash box doors should be regulated by a lever and ratchet, or any other practical arrangement.

Twin Screw Propulsion.

The object of two screws at the stern of a ship is for steering and light draughts. The proportions of the engines, screws, and boilers, will be as for those already given, for the reason that although the screw and engines are smaller, the power required at a given amount of displacement of the ship will be the same. The remaining proportions relative to land and marine engines, and boilers, will be found under the following head of Miscellaneous.

MISCELLANEOUS.

Position of Eccentric.

The angle of the eccentric in relation to that of the crank will be produced thus:

First. Describe on the centre of the crank shaft a circle equal to the travel of the slide valve.

Secondly. Draw the centre line of the angle of the crank at full or half stroke.

Thirdly. The intersection of the circle (denoting the travel of the slide valve) with that of the centre line of the crank is the starting point to ascertain the angle of the eccentric.

Fourthly. From this point of intersection set off a distance or dimension on the centre line of the crank equal to the travel of valve from edge of supply steam port, minus lead of slide valve.

Fifthly. At the point where this distance intersects with the centre line alluded to, draw a line at right angles with the centre line of crank.

Sixthly. Lines drawn from the centre of crank shaft to the intersections of the circle will be the angle of the eccentric either for ahead or astern.

Radius of Slide Valve Link.

The radius of the slide valve link for horizontal or vertical engines will be thus deduced:

First. Set the slide at half stroke.

Secondly. From end of slide valve set off half the travel, plus the clearance; from this last point set off the distance from inside of casing, to the extremity of oil cup of the gland of valve rod, plus clearance.

Thirdly. From point of clearance last alluded to, set off centre of block pin.

Fourthly. From centre of block pin to centre of crank shaft will be the radius of the link.

Marine Screw Engines, Direct Acting.

The angle of the eccentrics in relation to that of the crank will be thus produced:

First. Describe on the circle of the crank shaft a circle equal to the travel of the slide valve.

Secondly. Draw the centre line of the angle of the crank at full or half stroke.

Thirdly. The intersection of the circle (denoting the travel of the valve) with that of the centre line of the crank, is the starting point to ascertain the angles of the eccentrics.

Fourthly. From the point of intersection furthest from the crank set up a distance or dimension, equal to width of supply steam port or opening caused by the slide valve, minus lead of slide valve.

Fifthly. At the point where this distance intersects with the centre line of crank, draw a line at right angles to it, the intersection of which on the circle will be the centres of the eccentrics.

Sixthly. Lines drawn from the centre of the crank to the centres of the eccentrics, will be the angles of the latter.

Radius of Slide Valve Link.

To obtain the curve of this link the following must be observed:

First. Set the slide valve at half stroke.

Secondly. From the front end of the slide valve set off half the travél of slide valve, plus clearance; from this, set off the distance from inside of casing to extremity of oil cup of the gland of valve rod, plus clearance.

Thirdly. From point of clearance last alluded to set off centre of block pin.

Fourthly. From centre of block pin to centre of crank shaft will be the radius required.

Oscillating Engines.

To obtain the radius of the sliding quadrant, the position of the centres of the stud pin of the levers (that work the slide valves) will be the principal guide, consequently when the slide valve is at half stroke, the levers are in a line with each other, the intersection of which with the centre line of the cylinder will be that of the sliding quadrant.

From the centre of the trunnion to the centre of the quadrant, will therefore be radius of the latter.

Length of the slot of the quadrant is subservient to the angle assumed by the piston rod at half stroke.

Radius of Valve Link.

Radius of valve link for oscillating engines will be thus:

From centre of quadrant set up a distance agreed on for centre of link block; from centre of block to centre of crank shaft equals radius required.

Where levers are used the action of the eccentrics will be reversed, consequently their position will be within the crank throw. The length of the eccentric rods = from centre of crank shaft to centre of link, when the pin is in its centre. When the pin is outside the centre of the link, the distance must be deducted from the length given, the remainder = the length of rods.

Paddle Wheels.

The mode to obtain the centres of the radius rods on the eccentric will be thus:

First. Determine the diameter of the pitch line, which must be sufficiently large to allow a clearance between each of the eyes of the rods. An approximate rule to obtain the diameter of the pitch line will be $1\frac{1}{2}$ to $1\frac{1}{4}$ inch for each float.

Secondly. From the centre of pitch circle of floats to centre of pitch circle of the eccentric will be the length of the radius rod.

Thirdly. With the length of the rod as a radius, and on the intersection of each lever with the

circle of eccentricity, as a centre, describe arcs intersecting with the pitch line of the eccentric.

Fourthly. The intersection lastly alluded to will be the centres for the radius rod's pins.

Proportions of Connecting Rods having Strap Ends.

Length of bearing = diameter of bearing × 1.5 to 1.25.

Thickness of brass (longitudinally) =

$$\frac{\text{diameter of bearing}}{5 \text{ to } 6}$$

Thickness of brass at side = thickness longitudinally × .5 to .4.

Thickness of flange = thickness of brass at sides.

Depth of flange = thickness of flange × 1 to .75.

Area of strap at centre of curve =

$$\frac{\text{area of bearing}}{3 \text{ to } 4}$$

Area of side of strap = area at centre of curve × .7 to .6.

Width of strap = diameter of bearing.

Thickness of strap at centre of curve and sides =

$$\frac{\text{area at each part}}{\text{width}}$$

Thickness of cotter and gib = diameter of bearing × .25 to .2.

Total width of cotter and gibs at centre = diameter of bearing × 1 to .875.

Width of cotter at centre = total width of cotter and gibs × .4.

Taper of sides of cotter = $\frac{1}{2}$ inch per foot.

Length of cotter beyond gibs (back end) = width of cotter at centre × 4 to 3.

Length of cotter beyond gibs (front end) = width of cotter at centre × 1.25 to 1.

Diameter of stop stud = $\frac{1}{8}$ of an inch per inch of bearing's diameter.

Thickness of strap at cotter part = thickness of strap at sides × 1.25.

Length of rod (wrought iron) beyond cotter = diameter of bearing × .6 to .5.

Length of rod (cast iron) beyond cotter = that for wrought iron × 1.25.

Length of strap beyond cotter = that of rod.

Depth of clip of gib = thickness of gib.

Width of clip of gib = depth of clip × .875.

Levers.

Thickness of metal of boss of eye

$$= \frac{\text{diameter of hole}}{3}$$

Length of boss of eye = diameter of hole.

Minimum length of lever = travel of lever.

Width of lever at bosses = diameter of hole + thickness of metal of one side of boss.

Thickness of lever at each end =

$$\frac{\text{diameter of hole}}{4}$$

In all cases the versed sine of the travel of the lever should be divided, so as to equalize the vibration.

KEYS AND COTTERS.

$$\text{Width of key} = \frac{\text{diameter of hole}}{4}$$

Taper of key = $\frac{1}{4}$ inch per foot.
Thickness of key = width × .75.

$$\text{Depth of key slot in shaft} = \frac{\text{thickness of key}}{3}$$

Keys in some cases have gib ends, the proportions being the same as for that of gibs.

Taper of cotter = $\frac{1}{4}$ inch per foot.
Width of cotter = diameter of bolt into which it is inserted.

$$\text{Thickness of cotter} = \frac{\text{diameter of bolt}}{4}$$

Length of bolt beyond cotter = diameter of bolt × 1 to .75.
Length of boss beyond extremity of bolt = diameter of bolt.

$$\text{Width of key for eccentrics} = \frac{\text{diameter of shaft}}{4 \text{ to } 6}$$

Use the latter for shafts 24 inches in diameter.

$$\text{Thickness of key} = \frac{\text{width}}{2}$$

Plummer Blocks.

Length of bearing = diameter × 1.5.

Thickness of brass = $\frac{3}{8}$ of an inch as a minimum for shafts $1\frac{1}{2}$ inches in diameter; above this thickness of brass above and below bearing = $\frac{\text{diameter of bearing}}{4 \text{ to } 6}$

Thickness of brass at the sides = $\frac{\text{diameter of shaft}}{8 \text{ to } 12}$

Thickness of flange of brass = that at the side.

Length of fitting strip of brass = thickness over bearing. These strips should be one within each flange of brass.

Diameter of cap bolts (2) = diameter of bearing × .3 to .25, using the latter for bearings 10 inches diameter. When 4 cap bolts are used, area of each bolt = area of each bolt when two are used × .6.

Width of cap = diameter of bearing.

Thickness of metal under brass = diameter of bearing × .5.

Thickness of cap = diameter of bearing × .5.

Width of metal between side of brass and side of cap bolt = diameter of bolt × .5.

Width of metal beyond bolt = diameter of bolt × 1 to .875.

Diameter of oil cup, external = diameter of bearing × .5 to .4.

Depth of oil cup = diameter of oil cup × .75.

Thickness of metal of oil cup at top = $\frac{1}{8}$ to $\frac{3}{8}$ of an inch.

Taper of side of oil cup = $\frac{1}{8}$ of an inch per inch in depth.

Approximate height of plummer block from centre of bearing to sole = diameter of bearing × 2 to 1.5.

Thickness of sole = thickness of cap × .5.

Thickness of sole plate = thickness of sole = 1.125.

Total area of sole plate bolts = total area of cap bolts × 1.25.

Diameter of nut bosses = width of nut across the angles × 1.1.

Width of facing strips = $\frac{1}{2}$ to $1\frac{1}{4}$ inch.

The facing strips should be at the extremities of the sole, with a cross strip at the centre

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Toothed Wheels (Gearing).

The diameter of the wheel will to a certain extent govern the pitch of the teeth if to please the eye. The following table and rules are deduced from practical results:

Diameter at Pitch Line. ft.	in.			Pitch of Teeth. in.
15	0	...	...	$3\frac{3}{4}$
14	0	...	...	$3\frac{1}{2}$
13	0	...	...	3
12	0	...	...	$2\frac{3}{4}$

Diameter at Pitch Line. ft. in.			Pitch of Teeth. in.
10 0	...	...	$2\frac{1}{2}$
8 0	...	...	$2\frac{1}{4}$
6 0	...	...	2
4 0	...	...	$1\frac{1}{2}$
3 0	...	...	$1\frac{1}{4}$
1 0	...	...	1
0 6	...	...	$\frac{1}{2}$

Breadth of teeth = pitch × 2.5.
Thickness = pitch, minus clearance × .5.
Clearance = $\frac{1}{32}$ of an inch per inch of pitch.
Length of tooth = pitch × .75.
Thickness of rim, arms, etc. = thickness of tooth.
Width of arm at rim = pitch × 2 to 3.
Taper of arm = $\frac{1}{4}$ to $\frac{3}{8}$ of an inch per foot of length.
An approximation for the diameter of the shaft = pitch of teeth × 3 to 2, or one inch as a minimum for wheels one foot in diameter, increasing one inch per foot above this.
Diameter of boss = diameter of shaft × 2.
Length of boss = breadth of teeth × 1.25.
Depth of web of arm at boss = width of web of arm.

It must be understood that in practice the clearance of the tooth at the bottom and at the pitch line should be equal, by which the clearance of the root and the top of the tooth can be obtained. For the use of students the following is observed;

In mitre and bevil gear, the pitch line to construct the shape of the tooth is produced from a line (at right angles to the angle of the gear) that intersects with the centre of the wheel, which is in principle, the unrolling of the periphery of the cone of the bevil or mitre wheel.

Fire Bars.

Length should never exceed 3 feet 6 inches.
Inclination for marine boilers = 2 inches per foot.
Inclination for land boilers = 1 inch per foot.
Depth of bar at centre = $1\frac{1}{2}$ to $1\frac{5}{8}$ of an inch per foot of length.
Depth of bar at ends = $\frac{3}{4}$ of an inch per foot of length.
Width of bar at ends = $\frac{3}{4}$ to 1 inch.
Taper of sides of bar = $\frac{1}{8}$ of an inch per inch.
Clearance for ashes = $\frac{1}{4}$ to $\frac{3}{8}$ of an inch.
Depth of centre bearing bar = depth of fire bar at centre.
Width of centre bearing bar = depth of fire bar at end × 2.
Width of end bearing bar = depth of fire bar at end.

Marine Coal Bunkers.

Thickness of plates, etc.:
Top plates, $\frac{1}{8}$ of an inch.

Bottom plates, $\frac{3}{16}$ of an inch.
Radii of curves, 6 to 12 inches.
Corner angle iron, $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$.
Stay angle iron, $2 \times 2 \times \frac{5}{16}$.
Stays, 3 feet pitch.
Temperature tubes, number = 1 per 30 tons of coal, in bunkers containing above 200 tons.
Number of cubic feet per ton of coal = 46.
Space between boilers, or width of stoke hole = 9 to 10 feet.
Minimum space allowed for passing behind cylinders or thrust block in screw alley = 12 inches; maximum space 18 inches.
Diameter of water pipe for lubricating or cooling bearings of shaftings = 1 to 3 inches. This piping is supplied with stop cocks to each bearing, the water being required when bearings have a tendency to become heated.

PROPORTIONS OF STEAM COCKS WITH PLUGS SECURED BY NUTS AND SCREWS.

Diam. of Hole.	Plug. Diam. at Centre.	Plug. Length of Taper.	Plug. Width of Opening.	Plug. Length of Opening.	Plug. Diam. of Screw.	Plug. Side of Square Head for Handle.	Plug. Depth of Head.	Outer Screwed End. Diam. of Screw.	Outer Screwed End. Length of Screw.	Outer Screwed End. Number of Threads to an inch.
$\frac{3}{8}$	$\frac{5}{8}$	$1\frac{5}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	18
$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{7}{8}$	$\frac{5}{16}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{4}$	$\frac{11}{16}$	15
$\frac{3}{4}$	1	$2\frac{5}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{11}{16}$	$\frac{9}{16}$	1	$\frac{7}{8}$	15
1	$1\frac{5}{16}$	$3\frac{3}{8}$	$\frac{9}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{5}{16}$	1	12
$1\frac{1}{4}$	$1\frac{9}{16}$	$3\frac{5}{8}$	$\frac{11}{16}$	$1\frac{7}{8}$	$\frac{9}{16}$	1	$\frac{11}{16}$	$1\frac{5}{8}$	$1\frac{1}{8}$	12
$1\frac{1}{2}$	$1\frac{7}{8}$	$4\frac{1}{8}$	$\frac{7}{8}$	$2\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{1}{4}$	12
2	$2\frac{1}{2}$	5	$1\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	1	$2\frac{5}{16}$	$1\frac{3}{8}$	12

PROPORTIONS OF STEAM COCKS, ETC.—*Continued.*

	Inner Screwed Socket End.							
Diam. of Hole.	Hexagon End, size over Angles.	Outside Length.	Diameter of Neck.	Internal Length of Screw.	Diameter Internal.	Thickness of Metal around Plug.	From end of Socket to Centre.	Total Length.
$\frac{3}{8}$	$\frac{15}{16}$	1	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{9}{16}$ bare	$\frac{1}{8}$	$1\frac{9}{16}$	3
$\frac{1}{2}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{5}{32}$	$1\frac{7}{8}$	$3\frac{5}{8}$
$\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{9}{16}$	$1\frac{1}{8}$	$\frac{13}{16}$	$\frac{7}{8}$ full	$\frac{3}{16}$	$2\frac{1}{8}$	$4\frac{1}{4}$
1	$1\frac{5}{8}$	$1\frac{13}{16}$	$1\frac{3}{8}$	$\frac{7}{8}$	$1\frac{3}{32}$	$\frac{1}{4}$	$2\frac{5}{8}$	$5\frac{3}{8}$
$1\frac{1}{4}$	2	2	$1\frac{5}{8}$	1	$1\frac{1}{2}$ full	$\frac{5}{16}$	3	$6\frac{1}{8}$
$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{3}{4}$ full	$\frac{3}{8}$	$3\frac{1}{2}$	$7\frac{1}{4}$
2	3	$2\frac{5}{8}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{16}$	$\frac{7}{16}$	$4\frac{1}{4}$	$8\frac{3}{8}$

PROPORTIONS OF COCKS FOR MARINE PURPOSES (STRAIGHTWAY).

Diam.	Diam. of Plug at Centre.	Length of Opening.	Width of Opening.	Top and Bottom Lap of Plug.	Thickness of Plug at Bottom.	Thickness of Shell at Centre.
1	$1\frac{1}{4}$	$1\frac{5}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{1}{4}$
$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{16}$ full	$\frac{5}{16}$
$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{11}{16}$	1	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{3}{8}$
$1\frac{3}{4}$	2	$2\frac{1}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{3}{8}$
2	$2\frac{3}{16}$	$2\frac{1}{2}$	$1\frac{5}{16}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{7}{16}$
$2\frac{1}{4}$	$2\frac{5}{8}$	$2\frac{13}{16}$	$1\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{7}{16}$
$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{16}$	$1\frac{5}{8}$	$\frac{11}{16}$	$\frac{5}{16}$	$\frac{1}{2}$
$2\frac{3}{4}$	$3\frac{1}{8}$	$3\frac{5}{16}$	$1\frac{13}{16}$	$\frac{11}{16}$	$\frac{5}{16}$	$\frac{1}{2}$
3	$3\frac{7}{16}$	$3\frac{1}{2}$	2	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{1}{2}$
$3\frac{1}{4}$	$3\frac{11}{16}$	4	$2\frac{3}{16}$	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{9}{16}$
$3\frac{1}{2}$	4	$4\frac{1}{4}$	$2\frac{3}{8}$	$\frac{13}{16}$	$\frac{5}{16}$	$\frac{9}{16}$
$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{9}{16}$	$2\frac{9}{16}$	$\frac{13}{16}$	$\frac{3}{8}$	$\frac{5}{8}$
4	$4\frac{1}{2}$	$4\frac{11}{16}$	$2\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{5}{8}$
$4\frac{1}{4}$	$4\frac{11}{16}$	5	$2\frac{15}{16}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{11}{16}$
$4\frac{1}{2}$	$5\frac{1}{8}$	$5\frac{3}{16}$	$3\frac{1}{8}$	$\frac{15}{16}$	$\frac{3}{8}$	$\frac{11}{16}$
$4\frac{3}{4}$	$5\frac{3}{8}$	$5\frac{1}{2}$	$3\frac{1}{4}$	$\frac{15}{16}$	$\frac{3}{8}$	$\frac{3}{4}$
5	$5\frac{5}{8}$	$5\frac{13}{16}$	$3\frac{7}{16}$	$\frac{15}{16}$	$\frac{3}{8}$	$\frac{3}{4}$
$5\frac{1}{4}$	$5\frac{15}{16}$	6	$3\frac{5}{8}$	$\frac{15}{16}$	$\frac{3}{8}$	$\frac{13}{16}$
$5\frac{1}{2}$	$6\frac{1}{8}$	$6\frac{3}{8}$	$3\frac{11}{16}$	1	$\frac{7}{16}$	$\frac{13}{16}$
$5\frac{3}{4}$	$6\frac{1}{2}$	$6\frac{1}{2}$	4	1	$\frac{7}{16}$	$\frac{7}{8}$
6	$6\frac{3}{4}$	7	$4\frac{1}{8}$	1	$\frac{7}{16}$	$\frac{7}{8}$
$6\frac{1}{2}$	$7\frac{1}{4}$	$7\frac{7}{8}$	$4\frac{1}{2}$	1	$\frac{7}{16}$	$\frac{7}{8}$
7	$7\frac{7}{8}$	$8\frac{1}{4}$	$4\frac{7}{8}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{15}{16}$
8	$9\frac{1}{2}$	$9\frac{1}{2}$	$5\frac{1}{4}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{15}{16}$

PROPORTIONS OF COCKS FOR MARINE PURPOSES —*Continued.*

Diam.	Depth of Stuffing Box.	Depth of Gland.	Diam. of Studs.	Thickness of Flanges.	Side and Depth of Square Head.	Flange to Centre.
1	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{2}$	$2\frac{1}{8}$
$1\frac{1}{4}$	$\frac{11}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{9}{16}$	$2\frac{1}{4}$
$1\frac{1}{2}$	$\frac{11}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{5}{8}$	$2\frac{1}{2}$
$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{11}{16}$	$2\frac{3}{4}$
2	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{4}$	3
$2\frac{1}{4}$	$\frac{13}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{13}{16}$	$3\frac{1}{4}$
$2\frac{1}{2}$	$\frac{13}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{8}$	$3\frac{1}{2}$
$2\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	1	$3\frac{3}{4}$
3	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$1\frac{1}{16}$	4
$3\frac{1}{4}$	$\frac{15}{16}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$1\frac{1}{8}$	$4\frac{1}{4}$
$3\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{16}$	$1\frac{3}{16}$	$4\frac{1}{2}$
$3\frac{3}{4}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$	$4\frac{3}{4}$
4	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{5}{16}$	5
$4\frac{1}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{3}{8}$	$5\frac{1}{4}$
$4\frac{1}{2}$	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{7}{16}$	$5\frac{1}{2}$
$4\frac{3}{4}$	$1\frac{3}{16}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{2}$	$5\frac{3}{4}$
5	$1\frac{3}{16}$	$\frac{9}{16}$	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{5}{8}$	6
$5\frac{1}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{3}{4}$	$6\frac{1}{4}$
$5\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{7}{8}$	$6\frac{1}{2}$
$5\frac{3}{4}$	$1\frac{5}{16}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	2	$6\frac{3}{4}$
6	$1\frac{3}{8}$	$\frac{11}{16}$	1	$\frac{1}{2}$	$2\frac{1}{8}$	7
$6\frac{1}{2}$	$1\frac{3}{8}$	$\frac{11}{16}$	1	$\frac{9}{16}$	$2\frac{1}{4}$	$7\frac{1}{4}$
7	$1\frac{7}{16}$	$\frac{11}{16}$	$1\frac{1}{8}$	$\frac{9}{16}$	$2\frac{1}{2}$	$7\frac{3}{4}$
8	$1\frac{1}{2}$	$\frac{11}{16}$	$1\frac{1}{4}$	$\frac{9}{16}$	$2\frac{5}{8}$	$8\frac{1}{2}$

Side of taper of plugs = 1 inch per foot.

PROPORTIONS OF BOLTS, NUTS, ETC.

Diam. of Bolt.	No. of V Threads to an in.	Diam. at bottom of Thread.	Width of Nut across Angles.	Width of Nut across Flats.	Depth of Nut.	Diam. of Head.	Depth of Head.
$\frac{1}{8}$	30	$\frac{3}{32}$	$\frac{1}{4}$ bare	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{1}{16}$
$\frac{3}{16}$	24	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{1}{8}$
$\frac{1}{4}$	20	$\frac{3}{16}$	$\frac{1}{2}$ full	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{16}$
$\frac{5}{16}$	18	$\frac{1}{4}$	$\frac{5}{8}$ full	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{1}{4}$
$\frac{3}{8}$	16	$\frac{1}{4}$ $\frac{1}{32}$	$\frac{11}{16}$ $\frac{1}{32}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{5}{16}$
$\frac{7}{16}$	14	$\frac{5}{16}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{16}$
$\frac{1}{2}$	12	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$
$\frac{5}{8}$	11	$\frac{1}{2}$	$1\frac{1}{4}$ bare	$1\frac{1}{16}$	$\frac{5}{8}$	1	$\frac{1}{2}$
$\frac{3}{4}$	10	$\frac{5}{8}$	$1\frac{1}{2}$ full	$1\frac{5}{16}$	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$
$\frac{7}{8}$	9	$\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$
1	8	$\frac{13}{16}$	2 full	$1\frac{3}{4}$	1	$1\frac{1}{2}$	$\frac{11}{16}$
$1\frac{1}{8}$	7	$\frac{15}{16}$	$2\frac{3}{32}$	$1\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{5}{8}$	$\frac{3}{4}$
$1\frac{1}{4}$	7	$1\frac{1}{32}$ full	$2\frac{5}{16}$ bare	2	$1\frac{1}{4}$	$1\frac{3}{4}$	$\frac{7}{8}$
$1\frac{3}{8}$	6	$1\frac{1}{8}$	$2\frac{1}{2}$ full	$2\frac{3}{16}$	$1\frac{3}{8}$	2	1
$1\frac{1}{2}$	6	$1\frac{1}{4}$	$2\frac{3}{4}$ bare	$2\frac{3}{8}$	$1\frac{1}{2}$	$2\frac{3}{16}$	$1\frac{1}{16}$
$1\frac{5}{8}$	5	$1\frac{3}{8}$	$2\frac{13}{16}$	$2\frac{7}{16}$	$1\frac{5}{8}$	$2\frac{5}{16}$	$1\frac{1}{8}$
$1\frac{3}{4}$	5	$1\frac{7}{16}$	$3\frac{1}{4}$	$2\frac{13}{16}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$
$1\frac{7}{8}$	$4\frac{1}{2}$	$1\frac{9}{16}$	$3\frac{7}{16}$ full	3	$1\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{5}{16}$
2	$4\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{1}{4}$	2	$2\frac{3}{4}$	$1\frac{3}{8}$
$2\frac{1}{4}$	4	$1\frac{7}{8}$	$4\frac{3}{16}$	$3\frac{5}{8}$	$2\frac{1}{4}$	$3\frac{1}{8}$	$1\frac{7}{16}$
$2\frac{1}{2}$	4	$2\frac{1}{8}$	$4\frac{5}{8}$	4	$2\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{5}{8}$
$2\frac{3}{4}$	$3\frac{1}{2}$	$2\frac{1}{4}$	5 bare	$4\frac{5}{16}$	$2\frac{3}{4}$	$3\frac{7}{8}$	$1\frac{3}{4}$
3	$3\frac{1}{2}$	$2\frac{9}{16}$	$5\frac{7}{16}$ bare	$4\frac{11}{16}$	3	$4\frac{1}{8}$	$1\frac{15}{16}$
$3\frac{1}{4}$	$3\frac{1}{4}$	$2\frac{13}{16}$ bare	$5\frac{3}{4}$ full	5	$3\frac{1}{4}$	$4\frac{1}{2}$	$2\frac{1}{8}$
$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{16}$	$6\frac{1}{8}$	$5\frac{5}{16}$	$3\frac{1}{2}$	$4\frac{7}{8}$	$2\frac{1}{4}$
	Square.						
$3\frac{3}{4}$	$1\frac{1}{2}$	$3\frac{1}{4}$	$6\frac{9}{16}$	$5\frac{11}{16}$	$3\frac{3}{4}$	$5\frac{1}{4}$	$2\frac{7}{16}$
4	$1\frac{1}{2}$	$3\frac{1}{2}$	$6\frac{7}{8}$ $\frac{1}{32}$	6	4	$5\frac{1}{2}$	$2\frac{9}{16}$
$4\frac{1}{4}$	$1\frac{7}{16}$	$3\frac{3}{4}$	$7\frac{5}{16}$ bare	$6\frac{5}{16}$	$4\frac{1}{4}$	$5\frac{13}{16}$	$2\frac{11}{16}$
$4\frac{1}{2}$	$1\frac{7}{16}$	$3\frac{7}{8}$	$7\frac{5}{8}$	$6\frac{5}{8}$	$4\frac{1}{2}$	$6\frac{1}{8}$	$2\frac{7}{8}$
$4\frac{3}{4}$	$1\frac{3}{8}$	$4\frac{1}{16}$	$8\frac{1}{16}$	7	$4\frac{3}{4}$	$6\frac{7}{16}$	3
5	$1\frac{3}{8}$	$4\frac{1}{4}$	$8\frac{3}{8}$ $\frac{1}{32}$	$7\frac{5}{16}$	5	$6\frac{3}{4}$	$3\frac{1}{8}$
$5\frac{1}{4}$	$1\frac{3}{8}$	$4\frac{7}{16}$	$8\frac{13}{16}$	$7\frac{5}{8}$	$5\frac{1}{4}$	$7\frac{1}{16}$	$3\frac{1}{4}$
$5\frac{1}{2}$	$1\frac{3}{8}$	$4\frac{5}{8}$	$9\frac{3}{16}$	8	$5\frac{1}{2}$	$7\frac{3}{8}$	$3\frac{3}{8}$
$5\frac{3}{4}$	$1\frac{1}{4}$	$4\frac{11}{16}$	$9\frac{5}{8}$	$8\frac{3}{8}$	$5\frac{3}{4}$	$7\frac{11}{16}$	$3\frac{5}{8}$
6	$1\frac{1}{4}$	$4\frac{7}{8}$	10 bare	$8\frac{5}{8}$	6	8	$3\frac{7}{8}$

Split pin's diameter = $\frac{1}{8}$ of an inch per inch of bolt's diameter.

Stop pin's diameter = $\frac{1}{8}$ to $\frac{5}{8}$ of an inch, or $\frac{1}{8}$ of an inch per inch of bolt's diameter below 5 inches.

Thickness of stop ring = diameter of stop pin × 2.

Width and diameter of stop ring is subservient to the nut used.

Pitch of bolts and studs in flanges = diameter of bolt × 8.

Depth of stud screwed into metal = diameter of stud × 1.5.

Thickness of metal beyond stud = diameter of stud × .75.

Width of flange to side of metal of body part = diameter of stud × 2.5.

Thickness of flanges (cast iron) of pipes =

$$\frac{\text{diameter of pipe}}{5 \text{ to } 9}$$

Diameter of bolts or studs for flanges of pipes (cast iron) = $\frac{1}{2}$ to $1\frac{1}{4}$ inch, using the latter for pipes 12 inches in diameter.

Thickness of collars and heads of pins =

$$\frac{\text{diameter of pin}}{2. \text{ to } 3.}$$

Diameter of collars and heads of pins = diameter of pin × 1.5.

Thickness of check nut = diameter of bolt × .7 to .5.

PROPORTIONS OF COPPER PIPES, BOLTS, ETC

Diameter of Pipe varying ¼ of an inch.	Number of Bolts.	Diameter of Pipe.	Diameter of Bolt.	Diameter of Pipe.	Thickness of Flange.	Thickness of Pipes.
1 to 1½	3					Steam, blow-off, and water, ¼ inch. Feed water, 3/16 inch. Exhaust steam, ⅛ inch.
1¾ " 2¾	4	1 to 2½	½	1 to 2¼	⅜	
3 " 4	5	2¾ to		2½ " 5	7/16	
4¼ " 5	6	6	9/16	5¼ " 8½	½	
5¼ " 6½	7	6¼ to		8¾ " 11½	9/16	
6¾ " 8¼	8	11	⅝	11¾ " 18½	⅝	
8½ " 9½	9	11¼		18¾ " 26	11/16	
9¾ " 10¼	10	to				
10½ " 11¼	11	26	¾			
11½ " 14½	12					
14¾ " 16	13					
16¼ " 18	14					
18¼ " 20	16					
20¼ " 22	18					
22¼ " 23¾	20					
23½ " 26	23					

PROPORTIONS OF ENGINES PRODUCED BY THE RULES

Proportions of an Engine of 20 HP Nominal.

Diameter of cylinder, $14\frac{5}{16}$ in.
Length of stroke, 28 in.
Depth of piston, $3\frac{1}{2}$ in.
Clearance at each end of the stroke, $\frac{1}{2}$ in.
Diameter of cylinder at cover, allowing for reboring, $14\frac{9}{16}$ in.
Diameter of piston rod, $2\frac{1}{4}$ in.
Thickness of metal of cylinder, 1 in.
Thickness of raised portions, $\frac{1}{4}$ in.
Length of raised portions, 2 in.
Thickness of metal of steam passages, $\frac{3}{4}$ in.
Thickness of back end cover, $\frac{3}{4}$ in.
Depth of fitting part of cover, 1 in.
Thickness of flanges, 1 in.
Thickness of ribs, $\frac{1}{2}$ in.
Internal diameter of recess for nut of piston rod, $4\frac{1}{4}$ in.
Diameter of studs for securing cover, 1 in.
Diameter of pitch circle, $17\frac{5}{8}$ in.
Thickness of metal beyond bolts, $\frac{3}{4}$ in.
Diameter of bosses or projections to receive nuts, $2\frac{1}{8}$ in.
Thickness of bosses, $\frac{1}{8}$ in.
Thickness of front end of cylinder, $\frac{3}{4}$ in.
Number of ribs, 4.

Thickness of ribs, $\frac{1}{2}$ in.
Position of supporting brackets (perpendicular), 10 in.
Thickness of sole, $1\frac{1}{8}$ in.
Thickness of ribs, $\frac{3}{4}$ in.
Space between ribs, $6\frac{1}{2}$ in.
Diameter of securing bolts, $1\frac{3}{8}$ in.
Number of bolts, 4.
Transverse distance of securing bolts, $14\frac{1}{8}\frac{5}{8}$ in.
Diameter of piston rod stuffing box, 4 in.
Depth of piston rod stuffing box, $3\frac{5}{8}$ in.
Thickness of metal of bush, $\frac{5}{16}$ in.
Depth of gland, $2\frac{7}{8}$ in.
Thickness of metal of stuffing box, $\frac{7}{8}$ in.
Diameter of studs for securing gland, $\frac{3}{4}$ in.
Metal around studs, $\frac{1}{2}$ in.
Depth of oil cup, $2\frac{1}{4}$ in.
Thickness of flange of gland, $\frac{5}{8}$ in.

Steam Ports, etc.

Area of steam port (supply), 10 sq. in.
Length of steam port (supply), $9\frac{5}{16}$ in.
Width of steam port (supply), $1\frac{1}{8}$ in.
Width of steam passage, $1\frac{1}{4}$ in.
Length of steam passage, $9\frac{5}{16}$ in.
Width of exhaust port, $1\frac{5}{8}$ in.
Exhaust port area, 15 sq. in.
Outside lap of slide valve, $\frac{3}{4}$ in.
Inside lap of slide valve, $\frac{1}{16}$ in.

Side lap of slide valve, $\frac{5}{8}$ in.
Width of bar, $1\frac{5}{8}$ in.
Position of valve facing from centre line $10\frac{3}{4}$ in.
Stroke of slide valve, $3\frac{3}{4}$ in.
Diameter of slide valve rod, $1\frac{1}{4}$ in.
Stuffing box diameter, $2\frac{1}{4}$ in.
Depth of stuffing box, 2 in.
Thickness of bush, $\frac{1}{8}$ in.
Depth of gland, $1\frac{1}{2}$ in.
Thickness of metal of stuffing box, $\frac{1}{2}$ in.
Diameter of studs, $\frac{1}{2}$ in.
Number of studs, 2.
Clearance for slide, $\frac{7}{16}$ in.
Depth of slide valve internally, $1\frac{5}{8}$ in.
Thickness of body of slide, $\frac{1}{2}$ in.
Thickness of flange of slide, $\frac{5}{8}$ in.
Position of rod from face, $1\frac{7}{8}$ in.

Slide Casing.

Thickness of casing, $\frac{3}{4}$ in.
Thickness of flange, $\frac{7}{8}$ in.
Width of flange, $2\frac{3}{8}$ in.
Diameter of studs, $\frac{3}{4}$ in.
Thickness of cover, $\frac{5}{8}$ in.
Diameter of studs, $\frac{5}{8}$ in.
Thickness of ribs, $\frac{3}{8}$ in.

Piston.

Thickness of body, $\frac{5}{8}$ in.
Thickness of ribs, $\frac{1}{2}$ in.

Diameter of packing ring studs, $\frac{5}{8}$ in.
Thickness of stud blocks, $\frac{11}{16}$ in.
Side of stud block (square), $1\frac{1}{8}$ in.
Thickness of spring at thickest part, $\frac{5}{8}$ in.
Thickness of spring at thinest part, $\frac{7}{16}$ in.

Piston Rod.

Taper of rod in piston, $\frac{1}{8}$ in.
Depth of nut, $1\frac{5}{8}$ in.
Diameter of screw, $2\frac{1}{8}$ in.
Diameter of securing bolts, $1\frac{5}{8}$ in.
Thickness of T end, $1\frac{5}{8}$ in.
Width of T end, $3\frac{1}{4}$ in.

Cross Head or Connecting Pin.

Diameter of cross head pin, $3\frac{1}{8}$ in.

Guide Block.

Bottom area of guide, 84 in.
Length of bottom of guide, 12 in.
Width of bottom of guide, 7 in.
Thickness of bottom of guide, $1\frac{3}{4}$.
Thickness of shoe, $\frac{7}{8}$ in.
Taper of adjusting part of shoe, $\frac{1}{4}$ in.
Diameter of adjusting stud, $\frac{3}{4}$ in.
Length of bearing of connecting pin, $4\frac{1}{2}$ in.
Thickness of back part, $1\frac{1}{4}$ in.
Thickness of front part, $\frac{5}{8}$ in.

Depth of recess for soft metal, $\frac{1}{8}$ in.
Thickness of cap, $1\frac{5}{8}$ in.
Width of cap, $3\frac{1}{4}$ in.
Diameter of securing bolts, $1\frac{5}{8}$ in.

Connecting Rod.

Length of connecting rod, 4 ft. 8 in.
Length of fork from centre of eye, $7\frac{1}{2}$ in.
Width of each fork, 3 in.
Thickness of fork, $1\frac{1}{2}$ in.
Thickness of metal around pin, $1\frac{1}{8}$ in.
Width of eye, $1\frac{15}{16}$ in.
Diameter of connecting rod (fork end), $2\frac{5}{8}$ in.
Diameter of connecting rod (crank end), $2\frac{7}{8}$ in.
Diameter of connecting rod (at centre), $3\frac{3}{16}$ in.
Diameter of crank pin, $3\frac{3}{8}$ in.
Length of bearing, $5\frac{1}{8}$ in.
Thickness of brasses at the end, $\frac{3}{4}$ in.
Thickness of sides of brasses, $\frac{5}{8}$ in.
Diameter of adjusting bolts, $1\frac{5}{8}$ in.
Thickness of metal between brass and side of bolt, $\frac{1}{4}$ in.
Thickness of brass at extremities of bearing, $\frac{9}{16}$ in.
Thickness of flanges of brasses, $\frac{5}{8}$ in.
Thickness of the head of connecting rod beyond brasses, $1\frac{3}{4}$ in.

Eccentric.

Throw, $1\frac{7}{8}$ in.
Thickness of boss, $1\frac{1}{8}$ in.

Thickness of ribs, $\frac{9}{16}$ in.
Number of ribs, 3.
Thickness of ring, $\frac{7}{8}$ in.
Depth of recess, $\frac{3}{16}$ in.
Thickness of sides of recess, $\frac{3}{16}$ in.

Eccentric Rod Band and Bolts.

Diameter of eccentric rod, T end, $1\frac{7}{8}$ in.
Length of eccentric rod, 4 ft. 8 in.
Diameter of eccentric rod at middle, 2 in.
Diameter of eccentric rod at lever end, $1\frac{5}{8}$ in.
Diameter of each bolt and stud, $1\frac{1}{4}$ in.
Thickness of T end, $1\frac{1}{4}$ in.
Thickness of band, $\frac{5}{8}$ in.
Thickness of flanges of band, $\frac{15}{16}$ in.
Width of band, $2\frac{5}{8}$ in.
Diameter of weigh shaft, $2\frac{1}{2}$ in.

Main Framing.

Thickness of metal, $\frac{3}{4}$ in.
Width of each side of frame, $7\frac{1}{8}$ in.
Depth of frame, $3\frac{9}{16}$ in.
Distance between centre of sides, $14\frac{5}{16}$ in.
Height of facing projections, $\frac{3}{16}$ in.
Diameter of bosses of securing bolts (6), $2\frac{3}{4}$ in.
Length of guide channel, 2 ft. 7 in.
Thickness of flange part of guide channel, $1\frac{1}{4}$ in.

Diameter of flange studs, 1¼ in.
Pitch of bolts, 10 in.
Thickness of metal on each side of bolts, ⅞ in.
Thickness of metal under guide, 1¾ in.
Diameter of holding down bolts (6), 1⅜ in.
Diameter of lever weigh shaft boss, 5 in.
Thickness of bush, $\frac{3}{16}$ in.
Diameter of crank shaft bearing, 4½ in.
Length of bearing, 6¾ in.
Position of centre of bearing from centre line of framing, 10 in.
Thickness of brass of bearing, ¾ in.
Diameter of adjusting bolts, 1⅞ in.
Thickness of cap, 2½ in.
Thickness of metal between brass and side of bolts, ½ in.
Thickness of metal above side of adjusting bolt, ⅞ in.
Thickness of clip, $\frac{7}{16}$ in.

Crank and Shaft.

Area of the crank, 16.91 sq. in.
Thickness of crank, 3⅜ in.
Width of crank, 5⅛ in.
Diameter of shaft beyond bearing, 5⅛ in.

Fly Wheel.

Weight of rim, 2 tons 10 cwt.
Diameter to centre of rim, 8 ft. 3 in.

Cubical contents of rim, 21,292 cub. in.
Depth of rim, 11 in.
Width of rim, 6¼ in.
Diameter of boss, 12 in.
Length of boss, 11¼ in.
Number of arms, 6.
Sectional area of arm, 11 in.
Width of arm at rim, 5⅛ in.
Taper of arm (in whole length), 1⅛ in.
Area of connecting bar, 15 sq. in.
Width of connecting bar, 3 in.
Depth of connecting bar, 5 in.
Depth of key, 3 in.
Width of key, ¾ in.
Width of boss rings, 2½ in.
Thickness of boss rings, 1⅛ in.

Feed Pump.

Cubical contents, 45.5 cub. in.
Stroke of pump, 6½ in.
Diameter of plunger, 3 in.
Thickness of body of plunger, ⅜ in.
Thickness of end, ½ in.
Diameter of plunger pin, 1⅜ in.
Diameter of stuffing box, 4½ in.
Depth of stuffing box, 2⅛ in.
Depth of gland, 1⅝ in.
Diameter of gland studs, ¾ in.
Thickness of flange, ¾ in.

Thickness of body of pump (cast iron), $\frac{5}{8}$ in.
Area of valve, 4.594 sq. in.

FEED PUMP RELIEF VALVE.

Diameter of valve, $2\frac{1}{2}$ in.
Diameter of spring, $2\frac{1}{2}$ in.
Diameter of each coil, $\frac{1}{4}$ in.
Number of coils, 7.
Space between coils, $\frac{3}{8}$ in.
Diameter of valve spindle, $\frac{1}{2}$ in.
Thickness of valve, $\frac{1}{4}$ in.

GOVERNOR.

Height of plane line from suspension, $12\frac{3}{4}$ in.
Number of revolutions per minute, 52.
Diameter of mitre gear, $5\frac{3}{4}$ in.
Pitch of teeth, $\frac{3}{4}$ in.
Diameter of weigh shaft, $1\frac{1}{2}$ in.
Number of revolutions of engine, 64.
Diameter of spindle, $1\frac{1}{4}$ in.
Diameter of pendulum, $\frac{11}{16}$ in.
Diameter of connecting levers, $\frac{5}{8}$ in.
Diameter of pins, $\frac{5}{8}$ in.
Thickness of lever slide, $\frac{3}{16}$ in.
Thickness of metal of top, $\frac{5}{16}$ in.
Thickness of metal of governor bracket, $\frac{5}{8}$ in.
Diameter of spindle and rods for governor valve, $\frac{1}{2}$ in.
Diameter of balls, $5\frac{1}{4}$ in.

Dimensions of a Condensing Beam Engine of 150 HP Nominal.

Diameter of cylinder, 57 in.
Stroke of engine, 9 ft.
Area of port supply for equilibrium valve, 172 sq. in.
Length of ports, 40 in.
Width of ports, 4⅜ in.
Diameter of piston rod, 5¾ in.
Diameter of stuffing box, 10 in.
Depth of stuffing box, 1 ft. 11 in.
Depth of gland, 11½ in.
Diameter of gland bolts, 1¾ in.
Number of gland bolts, 4.
Thickness of body of cylinder, allowing for reboring, 1⅜ in.
Thickness of cover, 1 in.
Diameter of studs, 1½ in
Thickness of ribs, ¾ in.
Diameter of bolts for securing cylinder, 3½ in.
Thickness of flange, 1½ in.
Thickness of equilibrium valves, casing, or nozzle, 1 in.
Diameter of securing stud of casing, 1 in.
Thickness of flanges, 1 in.
Area of valve (supply) equilibrium, 115 sq. in.
Diameter of valve (supply) equilibrium; 12⅛ in.
Area of exhaust valve, 172 sq. in.
Diameter of exhaust valve, 14⅞ in.
Angle of mitre, 45°.

Width of mitred part of valve seat (mitre), $\frac{7}{8}$ in.
Depth of valve between seats, $4\frac{3}{8}$ in.
Thickness of valve, $\frac{3}{8}$ in.
Diameter of studs for securing valve seats, $\frac{3}{4}$ in.
Diameter of valve rod, $1\frac{1}{2}$ in.
Stuffing box diameter, 3 in.
Depth of stuffing box, 3 in.
Depth of gland, $2\frac{1}{4}$ in.
Diameter of studs for gland of valve's rod, $\frac{3}{4}$ in.
Number of studs for gland of valve's rod, 2.
Diameter of cam shaft, $4\frac{1}{2}$ in.
Length of main beam (cast iron), 36 ft.
Length of piston connecting rod, 4 ft. 6 in.
Length of parallel rod, 8 ft. 8 in.
Length of radius rod, 10 ft.
Diameter of piston connecting rod, $5\frac{3}{4}$ in.
Diameter of parallel connecting rod, $2\frac{3}{4}$ in.
Diameter of parallel rod, or bar and radius rod, $2\frac{3}{4}$ in.
Diameter of radius rod and parallel bar weigh shaft, $3\frac{1}{2}$ in.
Diameter of piston cap pin, 7 in.
Diameter of beam end pin, 7 in.
Depth of main beam at middle, 5 ft.
Diameter or depth at end, 2 ft.
Thickness of beam (2 parts or sides), $1\frac{1}{2}$ in.
Thickness of ribs of beam, $1\frac{7}{8}$ in.
Width of ribs and web, $4\frac{1}{2}$ in.
Diameter of gudgeon, $11\frac{1}{2}$ in.
Diameter of bosses for pins, 1 ft. $5\frac{1}{2}$ in.

Depth of bosses for pins, 9 in.
Diameter of gudgeon boss, 1 ft. 11 in.
Thickness of ribs, 1 in.

Connecting Rod.

Length of connecting rod, 27 ft.
Area at centre, 127 sq. in.
Width of cross part, 20 in.
Diameter of crank pin, 8 in.
Length of crank pin, 12 in.
Length of crank end of connecting rod, 10 ft.
Sectional area at crank end, 42 sq. in.
Diameter of connecting rod at termination of cross, crank end, 15 in.
Diameter of connecting rod at termination of cross, beam end, 13⅛ in.

Crank Shaft.

Diameter of crank shaft, 14⅝ in.

Crank Wrought Iron.

Thickness of metal of boss around shaft, 5¼ in.
Thickness of metal of boss around pin, 2⅞ in.
Area of crank at centre, 162 sq. in.
Depth of boss for shaft end of crank, 14⅝ in.
Depth of boss for pin end of crank, 8 in.

Gear for Working Valves.

Diameter of gear shaft, 5⅞ in.
Pitch of mitre gear, 1⅜ in.
Diameter of wheel, 1 ft. 10 in.

Fly Wheel.

Diameter of fly wheel at centre of rim, 25 ft.
Weight of rim, 15 tons.
Depth of rim, 15 in.
Width of rim, 9 in.
Area of rim, 135 sq. in.
Number of arms, 8.
Sectional area of each arm, 44 sq. in.
Width of arm at rim, 1 ft.
Diameter of centre of wheel, 5 ft.
Diameter of bolts for securing arms, 1¾ in.
Width of key, ¾ in.
Thickness of boss, 5¼ in.
Length of boss, 23 in.
Thickness of body, 1⅞ in.
Thickness of ribs, 1½ in.
Thickness of rings, 1¾ in.
Width of rings, 3½ in.

Pumps

Cubic contents of air pump (single acting), 22 ft.
Cubic contents of condenser, 23 ft.
Stroke of air pump, 3 ft.

Diameter of air pump, 3 ft. 1 in.
Cubic contents of cylinder, 159 ft.
Cubic contents of feed pump, 1537 in.
Stroke of feed pump, 3 ft.
Diameter of feed pump, 7⅜ in.
Diameter of air pump rod, 4½ in.
Diameter of feed pump rod, 1¾ in.

Proportions of a Pair of Marine Screw Engines 200 HP collectively.

Diameter of cylinder, 46⅝ in.
Area of cylinder, 1705.54 sq. in.
Length of stroke, 2 ft. 6 in.

Cylinder.

Thickness of metal of cylinder, 1⅛ in.
Thickness of metal of steam passage, ¾ in.
Thickness of flanges, 1⅛ in.
Diameter of flange studs, 1⅛ in.
Pitch of bolts, about 9 in.
Thickness of cover, ¾ in.
Thickness of ribs, ⅝ in.
Diameter of boring hole, 10 in.
Area of opening (or travel of valve from edge of port), 93¾ sq. in.
Area of port, 142⅜ sq. in.
Width of opening, 2⅞ in.
Length of port, 33½ in.

Width of port, $4\frac{1}{4}$ in.
Length of exhaust port, $33\frac{1}{2}$ in.
Width of exhaust port, $9\frac{7}{8}$ in.
Width of bar $1\frac{1}{2}$ in.

SLIDE VALVE.

Outside lap of valve, $1\frac{3}{4}$ in.
Inside lap of valve, $\frac{5}{16}$ in.
Width of exhaust space, $12\frac{1}{4}$ in.
Diameter of valve rod, $1\frac{7}{8}$ in.
Width of slide ring, $1\frac{1}{4}$ in.
Thickness of slide ring, 1 in.
Thickness of packing ring, 1 in.
Depth of recess in packing ring, $1\frac{1}{4}$ in
Diameter of set screws, $\frac{3}{4}$ in.
Pitch of set screws, $10\frac{1}{2}$ in.

VALVE CASING.

Thickness of metal, $\frac{3}{4}$ in.
Diameter of bolts or studs, $\frac{3}{4}$ in.
Thickness of flanges, $\frac{7}{8}$ in.
Thickness of cover of casing, $\frac{3}{4}$ in.
Thickness of ribs of flanges, $\frac{3}{4}$ in.
Thickness of ribs of cover, $\frac{9}{16}$ in.
Depth of ribs of cover, 4 in.
Diameter of securing studs of cover, $\frac{3}{4}$ in.

PISTON.

Depth of piston, 5 in.
Thickness of body, 1 in.

Thickness of metal around rods, 2 in.
Thickness of ring spring opposite slit, 1 in.
Thickness of ring spring at slit, $\frac{5}{8}$ in.
Thickness of packing ring, $1\frac{1}{4}$ in.
Diameter of packing ring studs, $\frac{3}{4}$ in.
Diameter of face ring studs, $\frac{7}{8}$ in.
Width of face ring, $1\frac{5}{8}$ in.
Thickness of face ring, 1 in.
Thickness of stud-blocks, $\frac{7}{8}$ in.
Side of square blocks, $1\frac{5}{8}$ in.
Piston rod (2 rods) diameter, $4\frac{1}{2}$ in.
Diameter of stuffing box, $6\frac{3}{4}$ in.
Depth of stuffing box, 4 in.
Depth of gland, 3 in.
Diameter of oil chamber, $6\frac{3}{4}$ in.
Thickness of metal of oil chamber, $\frac{3}{16}$ in.
Depth of stuffing box beyond oil chamber, $1\frac{1}{2}$ in.
Diameter of gland, $5\frac{7}{8}$ in.
Diameter of studs for main gland (3), $1\frac{1}{4}$ in.

Condenser.

Cubic contents (for two cylinders), 9 ft.
Thickness of body, 1 in.
Thickness of securing flanges, $1\frac{1}{4}$ in.
Thickness of doors, $\frac{3}{4}$ in.
Diameter of securing studs (doors), $\frac{3}{4}$ in.

Air Pump.

Cubic contents of air pump (double acting), 2.9 ft.
Stroke of air pump, 2 ft. 6 in.

Diameter of pump, $14\frac{3}{4}$ in.
Total area of one set of valves, 128 sq. in.
Area of openings in one valve, 16 sq
Number of one set of valves, 8.

VALVES, ETC.

Diameter of valves, $6\frac{1}{2}$ in.
Thickness of valve, $\frac{5}{8}$ in.
Lap of valve, $\frac{5}{16}$ in.
Lift of valve, $1\frac{1}{2}$ in.
Thickness of flange, $\frac{7}{16}$ in.
Diameter of securing studs, $\frac{3}{4}$ in.
Thickness of ribs, $\frac{3}{16}$ in.
Depth of ribs, $\frac{5}{8}$ in.
Diameter of securing bolts for guards, $\frac{3}{4}$ in.
Diameter of boss of securing bolts, $1\frac{1}{2}$ in.
Radius of curve of guard, $3\frac{1}{2}$ in.
Thickness of guard, $\frac{3}{16}$ in.
Diameter of exhaust steam pipe, 19 in.
Area of injection (water), 17 sq. in.
Diameter of injection pipe, $3\frac{3}{4}$ in.
Thickness of lining of air pump, $\frac{3}{8}$ in.
Depth of piston, 4 in.
Thickness of metal of body of piston, $\frac{7}{16}$ in.
Thickness of ribs (5), $\frac{5}{16}$ in.
Diameter of air pump rod, $2\frac{3}{8}$ in.
Proportions of stuffing box and gland as for piston rod.
Area of exhaust pipe (water) 188.69 sq. in.

Diameter of exhaust pipe (water), $15\frac{1}{2}$ in.
Area of snifting valve, 7 sq. in.
Diameter of snifting valve, 3 in.
Length of openings of injection valve, $3\frac{1}{2}$ in.
Width of openings, $\frac{7}{8}$ in.
Number of openings, 3.
Thickness of metal of body, $\frac{5}{16}$ in.
Thickness of flanges, $\frac{5}{8}$ in.
Diameter of valve rod, $\frac{5}{8}$ in.

Feed Pump.

Length of stroke, 2 ft. 6 in.
Cubic contents, 229.80 in.
Area of plunger, 7.66 sq. in.
Diameter of plunger, $3\frac{1}{8}$ in.
Thickness of plunger, $\frac{3}{8}$ in.
Diameter of pump rod, $1\frac{1}{2}$ in.
Area of feed valve, 7 sq. in.
Diameter of opening in valve, $4\frac{1}{4}$ in.

Guide Block.

Area of guide block face, 13.5 sq. in.
Length of guide block face, 1 ft. 6 in.
Width of guide block face at bottom, $7\frac{1}{2}$ in.
Width of guide block face at top, 2 in.
Thickness of guide, $1\frac{3}{4}$ in.
Diameter of securing cap bolts, $3\frac{1}{4}$ in.
Thickness of metal around bolt, $\frac{1}{2}$ in.

Diameter of bolt head, 4⅞ in.
Thickness of bolt head, 1⅝ in.
Diameter of pin, 5⅝ in.
Diameter of bearing, 5⅝ in.
Length of bearing, 7⅛ in.
Thickness of metal at back, 1⅞ in.
Thickness of metal at front, 1⅛ in.
Thickness of metal of projection, 1 in.
Thickness of metal of block, ⅞ in.
Diameter of screw of shoe, ¾ in.
Thickness of cap, 2⅞ in.
Sectional area of cross head, 24 sq. in.
Width, 5½ in.
Thickness of cap, 2⅞ in.

Guide Frame.

Thickness of flange, 1½ in.
Thickness of bottom of channel, 1½ in.
Diameter of flange securing bolts, 1⅛ in.
Pitch of bolts, 10½ in.
Thickness of metal of body and ribs, 1 in.
Width of ribs, 6 in.
Thickness of flanges, 1¼ in.
Diameter of securing studs or bolts, 1¼ in.

Connecting Rod

Length of connecting rod, 6 ft. 3 in.
Diameter of connecting rod at guide end, 4½ in.

Diameter of connecting rod, crank end, $5\frac{1}{8}$ in.
Diameter of connecting rod in centre, $5\frac{7}{8}$ in.
Width of each fork, $5\frac{5}{8}$ in.
Thickness of each fork, $2\frac{1}{4}$ in.
Space between forks, $7\frac{1}{8}$ in.
Diameter of eye, $9\frac{3}{8}$ in.
Width of eye, $3\frac{3}{8}$ in.
Length from centre of eye, $11\frac{1}{4}$ in.
Diameter of bearing (crank), 9 in.
Thickness of brass, $1\frac{1}{8}$ in.
Thickness of caps, 3 in.
Diameter of bolts, $3\frac{1}{4}$ in.
Diameter of heads, $4\frac{7}{8}$ in.
Thickness, $1\frac{5}{8}$ in.

Solid Link.

Area, 6.187 sq. in.
Thickness of link, $2\frac{3}{4}$ in.
Width of link, $2\frac{1}{4}$ in.
Length of sliding block, 4 in.
Thickness of block front, back and sides, $\frac{5}{8}$ in.
Diameter of projection, $1\frac{7}{8}$ in.
Length of projection, $1\frac{1}{8}$ in.
Width of portion secured to valve rod, $3\frac{3}{4}$ in.
Diameter of securing studs (3), $\frac{5}{8}$ in.

Eccentric Bands, Bolts, and Rods.

Throw of eccentric, $4\frac{5}{8}$ sq. in.
Area of solid link pin, 2.073 sq. in.

Diameter of solid link pin, $1\frac{5}{8}$ in.
Area of band bolts, 1.767 sq. in.
Diameter of band bolts, $1\frac{1}{2}$ in.
Width of band, 3 in.
Thickness of boss of eccentric, $1\frac{1}{2}$ in.
Thickness of rim and arms, $1\frac{1}{4}$ in.
Depth of recess, $\frac{3}{16}$ in.
Width of rim, arms, and boss, $3\frac{1}{2}$ in.
Thickness of band, 1 in.
Thickness of internal brass hoop, $\frac{1}{4}$ in.
Width of projection of brass hoop, $1\frac{1}{4}$ in.
Diameter of eye, $3\frac{1}{4}$ in.
Width of eye, 1 in.
Area of eccentric rod at eye, 2.625 sq. in.
Width of rod, 3 in.
Thickness at eye, $\frac{7}{8}$ in.
Thickness of bolt's flange, $1\frac{1}{2}$ in.

Crank and Shaft.

Throw of crank, 1 ft. 3 in.
Diameter at bearing, 9 in.
Diameter beyond bearing, $10\frac{1}{8}$ in.
Length of bearing, 18 in.
Diameter of crank pin, 9 in.
Length of crank pin, $6\frac{3}{4}$ in.
Area of each crank at centre, 46.828 sq. in.
Width of each crank at centre, $10\frac{1}{8}$ in.
Thickness of crank, $4\frac{5}{8}$ in.
Taper of sides of crank, $1\frac{1}{4}$ in.

MAIN FRAME.

Thickness of brass between flanges, 1 in.
Length of brass between flanges, 12 in.
Thickness of flange, $\frac{3}{4}$ in.
Thickness of brass at ends, $\frac{3}{4}$ in.
Diameter of securing bolts for cap, $3\frac{1}{4}$ in.
Space between bearing and side of bolts, $\frac{3}{16}$ in.
Width of bolt's keys, $3\frac{1}{4}$ in.
Thickness of bolt's keys, $\frac{7}{8}$ in.
Diameter of stay, $3\frac{1}{4}$ in.
Thickness of securing head, $1\frac{5}{8}$ in.
Area of securing bolt for head, 2.073 sq. in.
Diameter of securing bolt (4) for head, $1\frac{5}{8}$ in.
Thickness of cap (wrought iron), $3\frac{5}{8}$ in.
Thickness of metal of framing beyond bearing, $4\frac{1}{2}$ in.
Thickness of metal around securing cap bolts, $1\frac{5}{8}$ in.
Thickness of metal of framing, $1\frac{1}{8}$ in.
Depth and width of ribs, $3\frac{3}{8}$ in.
Thickness of bottom flange, $1\frac{3}{4}$ in.
Width of flange, 9 in.
Diameter of securing bolts or coach screws, $1\frac{5}{8}$ in.
Pitch of flange securing bolts, $14\frac{1}{2}$ in.

THRUST BLOCK AND SCREW SHAFT BLOCK.

Number of rings, 7.
Width of each ring, $1\frac{1}{4}$ in.
Space between rings, $1\frac{1}{4}$ in.

Depth of rings, 1 in.
Thickness of brasses, 1 in.
Number of staying recesses, 3.
Number of bolts for securing cap, 4.
Diameter of bolts, 1½ in.
Thickness of cap and bottom of block, 2½ in.
Depth of cap bolts, lugs, or bosses, 4⅛ in.
Thickness of metal around bolts, 1 in.
Diameter of bolts for securing block and sole plate, 1½ in.
Diameter of the bolts for securing block to plate, also secure the sole to frame, 1½ in.
Number of bolts, 6.
Thickness of sole plate, ribs, and bottom, 2½ in.
Length of sole plate beyond thrust part of block towards engine, 9 in.
Length of block and sole plate, beyond block towards screw, 2 ft. 2 in.
Length of plummer block for shaft, 12⅝ in.
Diameter of cap bolts, 1⅛ in.
Thickness of brasses, ¾ in.
Thickness of cap and bottom of block, 1¾ in.

Turning Gear and Coupling.

Diameter of wheel, 4 ft.
Diameter of worm, 6 in.
Pitch of teeth, 2½ in.
Length of worm, 10 in.
Diameter of worm shaft, 2½ in.

Diameter of wheel boss, 1 ft. 6 in.
Thickness of rim and body of wheel, 1¼ in.
Length of boss, 9 in.
Area of bolts, 49.576 sq. in.
Number of bolts, 7.
Diameter of bolts, 3 in.
Thickness of coupling at pitch line, 4 in.
Thickness of metal beyond bolt, 2¼ in.
Length of arm of ratchet, 7 ft. 6 in.

Wrought Iron Coupling.

Thickness of disc, 3 in.
Area of bolts, 49.576 sq. in.
Diameter of bolts, 3 in.
Number of bolts, 7.

Stern Tube and Stuffing Box.

Length of provisional bearing of friction part at stern end, 18 in.
Thickness of tubes, ½ in.
Depth of stuffing box, 22½ in.
Depth of gland, 5½ in.
Thickness of gland, 1 in.
Diameter of gland bolts, 1 in.
Number of gland bolts, 5.
Diameter of bolts for securing stern tube, 1 in.
Pitch of bolts, 8 in.
Thickness of flange, 1 in.

Screw Propeller.

Diameter of screw, 11 ft.
Pitch, 16 ft. 6 in.
Diameter of bearing, 11¼ in.
Diameter of boss, 13½ in.

Banjo, or Lifting Frame.

Diameter of lifting pin, 3 in.
Thickness of body of frame, ½ in.
Width of sides of frame, 6¾ in.
Depth of cross part (midway from centre to sides), 13½ in.
Depth at centre, 1 ft. 8¼ in.
Diameter of rope pulley, 1 ft.
Thickness of body, ¼ in.
Diameter of bosses, 4½ in.
Width of groove, 3 in.
Diameter of pin, 1⅞ in.
Diameter of catch pin, 1⅜ in.
Diameter of boss for catch pin, 2¾ in.
Depth of catch, 2¾ in.
Diameter of screw for adjusting stop lever, 1⅞ in.
Depth of stop lever at centre, 6 in.
Thickness of stop lever, 3 in.
Depth of lever at boss and clutch, 3 in.
Thickness of catch at joint, 1¾ in.
Thickness of bottom of bearing block and cap, 2⅞ in.
Thickness of tube, ⅜ in.

Thickness of each strip of lignum vitæ, $\frac{1}{2}$ in
Width of each strip of lignum vitæ, $1\frac{1}{2}$ in.
Thickness of metal between strips, $\frac{7}{16}$ in.
Diameter of bolts in cap (4), $1\frac{3}{4}$ in.

Stern Bracket.

Thickness of metal, $\frac{5}{8}$ in.
Diameter of securing bolts, 1 in.
Proportion of lignum vitæ strips as before.
Pitch of ratchet, $2\frac{1}{2}$ in.

Proportions of Oscillating Engines of 400 HP collectively.

Diameter of cylinder, $74\frac{1}{4}$ in.
Length of stroke, 6 ft.
Thickness of metal, $1\frac{5}{8}$ in
Area of steam (2) ports supply opening, 200 sq. in.
Length of steam ports supply, 37 in.
Width of exhaust, (1) $6\frac{3}{16}$ in.
Outside lap of valve, $1\frac{1}{4}$ in.
Inside lap of valve, $\frac{1}{4}$ in.
Width of opening (caused by slide), $2\frac{3}{4}$ in.
Width of port $4\frac{1}{8}$ in.
Width of bar in cylinder, $4\frac{1}{4}$ in.
Width of flange of valve, $4\frac{1}{4}$ in.
Length of piston rod, 10 ft. 6 in.
Diameter of piston rod, 9 in.
Diameter of cap bolts (2), $4\frac{1}{2}$ in.

Thickness of cap and head, $4\frac{1}{2}$ in.
Thickness of brasses, $1\frac{3}{8}$ in.
Depth of key, 9 in.
Thickness of key, $2\frac{1}{4}$ in.
Diameter of stuffing box of piston rod, $13\frac{1}{2}$ in.
Depth of stuffing box of piston rod, 9 in.
Depth of bush, 1 ft. 8 in.
Thickness of bush, $\frac{9}{16}$ in.
Depth of gland, $4\frac{1}{2}$ in.
Thickness of metal of stuffing box, $2\frac{1}{4}$ in.
Diameter of oil cup, $13\frac{1}{2}$ in.
Depth of oil cup, $4\frac{1}{2}$ in.

Trunnions and Steam Passages.

Area of steam passages, 229 sq. in.
Width of steam passage, $6\frac{5}{16}$ in.
Length of steam passage, 37 in.
Thickness of metal of passage, $1\frac{3}{8}$ in.
Area of steam openings in trunnions, 458 sq. in.
Thickness of metal of steam pipe, $\frac{3}{8}$ in.
Diameter of opening, $24\frac{1}{4}$ in.
Length of bearing of trunnions, 12 in.
Thickness of gland, 2 in.
Thickness of metal of trunnion at neck, $4\frac{1}{8}$ in.
Thickness of trunnion at stuffing box, 3 in.
Thickness of flange of trunnion, 3 in.
Depth of stuffing box, $14\frac{1}{2}$ in.
Depth of gland, $5\frac{7}{8}$ in.
Diameter of gland studs, $1\frac{1}{4}$ in.

Pitch of studs in gland and flange of pipes, 10 in.
Thickness of brasses for trunnion, $2\frac{1}{2}$ in.
Thickness of cap (cast iron), $8\frac{1}{2}$ in.
Diameter of bearing, 2 ft. $10\frac{1}{2}$ in.
Diameter of cap bolts, (2) $4\frac{5}{8}$ in.
Diameter of securing bolts, $4\frac{5}{8}$ in.
Thickness of metal under trunnion brasses, $8\frac{1}{2}$ in.

Air Pump and Condenser.

Cubical contents of one cylinder, 180 ft.
Cubical contents of condenser, 45 ft.
Cubical contents of each air pump, 22.5 ft.
Stroke of air pump, 3 ft.
Diameter of air pumps (2), 3 ft. $1\frac{1}{4}$ in.
Area of valves, 272 sq. in.
Diameter of connecting rod, $4\frac{3}{4}$ in.
Diameter of pin for piston, $4\frac{3}{4}$ in.
Thickness of trunk at neck, $\frac{7}{16}$ in.
Area of cap bolts (each) 4.43.
Diameter of cap bolts, $2\frac{3}{8}$ in.
Thickness of keying socket, $1\frac{3}{8}$ in.

Crank Shaft.

Diameter of crank shaft, $15\frac{3}{8}$ in.
Length of bearing, 2 ft. $6\frac{3}{4}$ in.

Crank Pin.

Diameter of crank pin, $10\frac{1}{2}$ in.
Length of bearing, 1 ft. $3\frac{3}{4}$ in.

Cranks.

Depth of shaft eye, 15⅝ in.
Depth of pin's eye, 10½ in.
Extreme diameter of eye (pin's), 19½ in.
Extreme diameter of eye (shaft), 25⅝ in.
Sectional area of each web of crank, 140 sq. in.

Lower Frame.

Thickness of metal of frame, 1½ in.
Depth of frame, 2 ft. 6 in.
Diameter of securing studs, 1½ in.

Entablature.

Diameter of cap bolts (2), 5¼ in.
Thickness of cap (cast iron), 7⅞ in.
Thickness of brass, 1¾ in.
Thickness of metal of body, 1⅝ in.
Thickness of solid sides of frame, 2¾ in.
Diameter of flange bolts, 1⅝ in.
Thickness of flange, 1½ in.
Depth of solid sides, 19 in.
Depth of frame beyond brass of bearing, 23 in.
Thickness of metal under brass, 4 in.
Diameter of stays (2) to each bearing of crank shaft, 5¼ in.
The remaining portions are as for screw engines.

Paddle Wheels.

Draught of ship, 10 ft.
Immersion of floats, 5 ft.

Number of floats immersed, 4.
Diameter of paddle at centre floats, 30 ft.
Length of float, 9 ft.
Width of float, 4 ft.
Number of floats, 14.
Area of each float, 36 ft.

Details of Paddle Wheels.

Diameter of centre, 8 ft.
Thickness of metal of boss, $3\frac{1}{2}$ in.
Length of boss, 2 ft. $6\frac{3}{4}$ in.
Diameter of eccentric shaft, $6\frac{3}{4}$ in.
Thickness of bushes, $\frac{3}{8}$ in.
Area of lever shaft, 6.4918.
Diameter of lever shaft, $2\frac{7}{8}$ in.
Diameter of lever pin, $2\frac{3}{8}$ in.
Diameter of radius rods, $2\frac{3}{8}$ in.
Thickness of metal of eccentric, $1\frac{1}{4}$ in.
Diameter of boss of eccentric shaft, $13\frac{1}{2}$ in.
Width of paddle wheel rings, $3\frac{1}{2}$ in.
Thickness of paddle wheel rings, $1\frac{1}{2}$ in.
Position of rings from ends of float, 2 ft. 3 in.

Proportions of a Land Boiler for a 20 HP Engine.

Number of square feet of heating surface, 226 sq. ft.
Length of boiler, 23 ft. 6 in.

Diameter of boiler, 5 ft. 6 in.
Diameter of tube, 2 ft. 9 in.
Depth of water line from top of boiler, 1 ft. 10 in.
Height of water line from top of tube, 6½ in.
Curved length of flues, 3 ft.
Heating surface of tube, 98 sq. ft.
Heating surface of bottom flue, 63 sq. ft.
Heating surface of side flues, 66 sq. ft.
Grate and fire bar surface, 18 sq. ft.
Area of side flues, 4.5 sq. ft.
Area of bottom flue, 4.5 sq. ft.
Width of bottom flue, 2 ft. 9 in.
Width of side flue, 10 in.
Length of grate, 6 ft. 6 in.
Area of safety valve, 18 sq. in.
Length of lever, 1 ft. 10 in.
Weight in lbs. on end of lever, 81 lbs.
Diameter of weight, 8 in.
Depth, 6⅛ in.
Pressure against valve in lbs., 720 lbs.
Distance from point of suspension to centre of valve, 2½ in.
Pressure in lbs. per square inch, 40 lbs.

Marine Boiler (Proportions) 200 HP nominal.

Total heating surface of tubes, 2500 sq. ft.
Diameter of tubes externally, 2½ in.
Length of tubes, 6 ft. 6 in.

Number of tubes, 500.
Internal diameter of tubes, 2¼ in.
Rake of inclination of tubes, 2½ in.
Water space, 5 in.
Diameter of stays, 1¼ in.
Position of stays at right angles above fire boxes, 15 in.
Position of stays at sides and bottom of fire boxes, 13 in.
Number of fire boxes, 5.
Width of fire box at tube, 2 ft. 10 in.
Fire bar or grate surface for one box, 20 sq. ft.
Length of fire bar grate surface, 6 ft. 8 in.
Width of fire bar grate surface, 3 ft.
Radius of top and bottom curves, 3 ft.
Area of fire box at grate, 10 sq. ft.
Depth of fire box at grate, 3 ft. 6 in.
Radius for small curves, 8 in.
Width of fire door opening, 2 ft. 8 in.
Cubic contents of steam capacity, 600 ft.
Height of water line above fire box at tube end, 7 in.
Width of fire box at back end, 18 in.
Width of smoke box at bottom, 16 in.
Area of opening in uptake, 15 sq. ft.
Diameter of surface blow off pipe, 3 in.
Diameter of bottom, 4 in.
Area of funnel (4 boilers), 40 sq. ft.
Diameter of funnel, 7 ft 2 in.

Height of water line of ship above top of boiler, 14 in.

Funnel to be telescopic.

Diameter of wheel shaft, 3 in.

Diameter of wheel, 22 in.

Pitch of teeth, 2 in.

Diameter of worm, $5\frac{1}{2}$ in.

Radius of handle, 14 in.

SAFETY VALVE.

Area of valve in square inches, 33.

Diameter of valve, $6\frac{1}{2}$ in.

Diameter of valve spindle, $1\frac{5}{8}$ in.

Diameter of weight, 13 in.

Pressure in lbs. against the valve, 660 lbs.

Thickness of casing, $\frac{5}{8}$ in.

Depth of guide ribs of valve, $3\frac{1}{4}$ in.

Diameter of lifting lever of weigh shaft, $1\frac{5}{8}$ in.

Length of lifting lever, $6\frac{3}{4}$ in.

Lift of valve, $1\frac{5}{8}$ in.

SUPERHEATING.

Length of tubes, 3 ft.

Total surface of tubes in square feet, 800.

Internal diameter of tubes, $3\frac{1}{2}$ in.

Thickness of metal of tubes, $\frac{1}{4}$ in.

Number of tubes, 256.

Table of Specific Gravities.

	Weight of a Cubic Inch in lbs.
Copper, cast	.3178
Iron, cast	.263
Iron, wrought	.276
Lead	.4103
Steel	.2827
Gun metal	.3177

Gravity of Water.

1 cubic foot	= 6.25 imperial gallons.
11.2 imperial gallons	= 1 cwt.
224 "	= 1 ton.
1 cubic ft. of sea water	= 642 lbs.
34.9 " "	= 1 ton.
277.274 cubic inches	= 1 imperial gallon.
1 gallon of fresh water	= 10 lbs.
1 gallon of sea water	= 10.25 lbs.

Algebraic Signs as applied in Mechanical Calculations.

= Sight of equality, and signifies equal to, as 2 added to $5 = 7$.

+ Sign of addition, and signifies plus or more, as $4 + 2 = 6$.

— Sign of subtraction, and signifies minus or less, as $7 - 5 = 2$.

× Sign of multiplication, and signifies multiplied by, as $7 \times 6 = 42$.

÷ Sign of division, and signifies divided by, as $20 \div 5 = 4$.

$\sqrt{}$ Sign of square root
$\sqrt[3]{}$ Sign of cube root
} evolution, or the extraction of roots, thus $\sqrt{81} = 9$ $\sqrt[3]{729} = 9$.

Fractions of a Foot in Inches.	Decimal Value in Feet.	Area in Feet.	Circumference in feet.
11	.9166	.6598	2.879
10	.8333	.54537	2.617
9	.75	.44178	2.356
8	.6666	.33779	2.094
7	.5833	.26722	1.832
6	.5	.19635	1.57
5	.4166	.1363	1.308
4	.3333	.08724	1.047
3	.25	.04908	.7854
2	.1666	.02179	.5233
1	.0833	.00544	.2616
$\frac{7}{8}$	.07291	.00417	.22907
$\frac{3}{4}$	.0625	.00306	.19635
$\frac{5}{8}$	.05208	.0028	.16362
$\frac{1}{2}$	.04166	.00136	.130899
$\frac{3}{8}$	.03125	.00076	,098174
$\frac{1}{4}$	.02083	.00035	.06545
$\frac{1}{8}$	.01041	.000085	.032719

Fractions of an Inch.	Decimal Value.	Fractions of an Inch.	Decimal Value.
$\frac{7}{8}$ & $\frac{3}{32}$	.96875	$\frac{3}{8}$ & $\frac{3}{32}$	.46875
$\frac{7}{8}$ & $\frac{1}{16}$	.9375	$\frac{3}{8}$ & $\frac{1}{16}$	.4375
$\frac{7}{8}$ & $\frac{1}{32}$	.90625	$\frac{3}{8}$ & $\frac{1}{32}$	.40625
$\frac{7}{8}$	.875	$\frac{3}{8}$	.375
$\frac{3}{4}$ & $\frac{3}{32}$	.84375	$\frac{1}{4}$ & $\frac{3}{32}$	.34375
$\frac{3}{4}$ & $\frac{1}{16}$	.8125	$\frac{1}{4}$ & $\frac{1}{16}$	.3125
$\frac{3}{4}$ & $\frac{1}{32}$	.78125	$\frac{1}{4}$ & $\frac{1}{32}$	.28125
$\frac{3}{4}$	.75	$\frac{1}{4}$	.25
$\frac{5}{8}$ & $\frac{3}{32}$	.71875	$\frac{1}{8}$ & $\frac{3}{32}$	.21875
$\frac{5}{8}$ & $\frac{1}{16}$	.6875	$\frac{1}{8}$ & $\frac{1}{16}$	.1875
$\frac{5}{8}$ & $\frac{1}{32}$	.65625	$\frac{1}{8}$ & $\frac{1}{32}$	.15625
$\frac{5}{8}$	.625	$\frac{1}{8}$	.125
$\frac{1}{2}$ & $\frac{3}{32}$	.59375	$\frac{3}{32}$	.09375
$\frac{1}{2}$ & $\frac{1}{16}$	.5625	$\frac{1}{16}$	.0625
$\frac{1}{2}$ & $\frac{1}{32}$	.53125	$\frac{1}{32}$	.03125
$\frac{1}{2}$	.5		

A Table of Diameters, Areas, and Circumferences of Circles, from $\frac{1}{16}$ of an Inch to 110 Inches.

Dia.	Area.	Circum.	Dia.	Area.	Circum.
$\frac{1}{16}$	.0030	.1963	$\frac{5}{16}$	4.2001	7.2649
$\frac{1}{8}$	.0122	.3927	$\frac{3}{8}$	4.4302	7.4613
$\frac{3}{16}$	.0276	.5890	$\frac{7}{16}$	4.6664	7.6576
$\frac{1}{4}$	.0490	.7854	$\frac{1}{2}$	4.9087	7.8540
$\frac{5}{16}$	.0767	.9817	$\frac{9}{16}$	5.1573	8.0503
$\frac{3}{8}$	.1104	1.1781	$\frac{5}{8}$	5.4119	8.2467
$\frac{7}{16}$	.1503	1.3744	$\frac{11}{16}$	5.6727	8.4430
$\frac{1}{2}$	.1963	1.5708	$\frac{3}{4}$	5.9395	8.6394
$\frac{9}{16}$	.2485	1.7671	$\frac{13}{16}$	6.2126	8.8357
$\frac{5}{8}$	.3068	1.9635	$\frac{7}{8}$	6.4918	9.0321
$\frac{11}{16}$	.3712	2.1598	$\frac{15}{16}$	6.7772	9.2284
$\frac{3}{4}$	.4417	2.3562			
$\frac{13}{16}$	.5185	2.5525	3 in.	7.0686	9.4248
$\frac{7}{8}$	.6013	2.7489	$\frac{1}{16}$	7.3662	9.6211
$\frac{15}{16}$	.6903	2.9452	$\frac{1}{8}$	7.6699	9.8175
			$\frac{3}{16}$	7.9798	10.0138
1 in.	.7854	3.1416	$\frac{1}{4}$	8.2957	10.2102
$\frac{1}{16}$	.8861	3.3379	$\frac{5}{16}$	8.6179	10.4065
$\frac{1}{8}$	.9940	3.5343	$\frac{3}{8}$	8.9462	10.6029
$\frac{3}{16}$	1.1075	3.7306	$\frac{7}{16}$	9.2806	10.7992
$\frac{1}{4}$	1.2271	3.9270	$\frac{1}{2}$	9.6211	10.9956
$\frac{5}{16}$	1.3529	4.1233	$\frac{9}{16}$	9.9678	11.1919
$\frac{3}{8}$	1.4848	4.3197	$\frac{5}{8}$	10.3206	11.3883
$\frac{7}{16}$	1.6229	4.5160	$\frac{11}{16}$	10.6796	11.5846
$\frac{1}{2}$	1.7671	4.7124	$\frac{3}{4}$	11.0446	11.7810
$\frac{9}{16}$	1.9175	4.9087	$\frac{13}{16}$	11.4159	11.9773
$\frac{5}{8}$	2.0739	5.1051	$\frac{7}{8}$	11.7932	12.1737
$\frac{11}{16}$	2.2365	5.3014	$\frac{15}{16}$	12.1768	12.3700
$\frac{3}{4}$	2.4052	5.4978			
$\frac{13}{16}$	2.5801	5.6941	4 in.	12.5664	12.5664
$\frac{7}{8}$	2.7611	5.8905	$\frac{1}{16}$	12.9622	12.7627
$\frac{15}{16}$	2.9483	6.0868	$\frac{1}{8}$	13.3640	12.9591
			$\frac{3}{16}$	13.7721	13.1554
2 in.	3.1416	6.2832	$\frac{1}{4}$	14.1862	13.3518
$\frac{1}{16}$	3.3411	6.4795	$\frac{5}{16}$	14.6066	13.5481
$\frac{1}{8}$	3.5465	6.6759	$\frac{3}{8}$	15.0331	13.7445
$\frac{3}{16}$	3.7582	6.8722	$\frac{7}{16}$	15.4657	13.9408
$\frac{1}{4}$	3.9760	7.0686	$\frac{1}{2}$	15.9043	14.1372

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
$\frac{9}{16}$	16.3492	14.3335	7 in.	38.4846	21.9912
$\frac{5}{8}$	16.8001	14.5299	$\frac{1}{16}$	39.1749	22.1875
$\frac{11}{16}$	17.2573	14.7262	$\frac{1}{8}$	39.8713	22.3839
$\frac{3}{4}$	17.7205	14.9226	$\frac{3}{16}$	40.5469	22.5802
$\frac{13}{16}$	18.1900	15.1189	$\frac{1}{4}$	41.2825	22.7766
$\frac{7}{8}$	18.6655	15.3153	$\frac{5}{16}$	41.9974	22.9729
$\frac{15}{16}$	19.1472	15.5716	$\frac{3}{8}$	42.7184	23.1693
			$\frac{7}{16}$	43.4455	23.3656
5 in.	19.6350	15.7080	$\frac{1}{2}$	44.1787	23.5620
$\frac{1}{16}$	20.1290	15.9043	$\frac{9}{16}$	44.9181	23.7583
$\frac{1}{8}$	20.6290	16.1007	$\frac{5}{8}$	45.6636	23.9547
$\frac{3}{16}$	21.1252	16.2970	$\frac{11}{16}$	46.4153	24.1510
$\frac{1}{4}$	21.6475	16.4934	$\frac{3}{4}$	47.1730	24.3474
$\frac{5}{16}$	22.1661	16.6897	$\frac{13}{16}$	47.9370	24.5437
$\frac{3}{8}$	22.6907	16.8861	$\frac{7}{8}$	48.7070	24.7401
$\frac{7}{16}$	23.2215	17.0824	$\frac{15}{16}$	49.4833	24.9364
$\frac{1}{2}$	23.7583	17.2788			
$\frac{9}{16}$	24.3014	17.4751	8 in.	50.2656	25.1328
$\frac{5}{8}$	24.8505	17.6715	$\frac{1}{16}$	51.0541	25.3291
$\frac{11}{16}$	25.4058	17.8678	$\frac{1}{8}$	51.8486	25.5255
$\frac{3}{4}$	25.9672	18.0642	$\frac{3}{16}$	52.8994	25.7218
$\frac{13}{16}$	26.5348	18.2605	$\frac{1}{4}$	53.4562	25.9182
$\frac{7}{8}$	27.1085	18.4569	$\frac{5}{16}$	54.2748	26.1145
$\frac{15}{16}$	27.6884	18.6532	$\frac{3}{8}$	55.0885	26.3109
			$\frac{7}{16}$	55.9138	26.5072
6 in.	28.2744	18.8496	$\frac{1}{2}$	56.7451	26.7036
$\frac{1}{16}$	28.8665	19.0459	$\frac{9}{16}$	57.5887	26.8999
$\frac{1}{8}$	29.4647	19.2423	$\frac{5}{8}$	58.4264	27.0963
$\frac{3}{16}$	30.0798	19.4386	$\frac{11}{16}$	59.7762	27.2926
$\frac{1}{4}$	30.6796	19.6350	$\frac{3}{4}$	60.1321	27.4890
$\frac{5}{16}$	31.2964	19.8313	$\frac{13}{16}$	60.9943	27.6853
$\frac{3}{8}$	31.9192	20.0277	$\frac{7}{8}$	61.8625	27.8817
$\frac{7}{16}$	32.5481	20.2240	$\frac{15}{16}$	62.7369	28.0780
$\frac{1}{2}$	33.1831	20.4204			
$\frac{9}{16}$	33.8244	20.6167	9 in.	63.6174	28.2744
$\frac{5}{8}$	34.4717	20.8131	$\frac{1}{16}$	64.5041	28.4707
$\frac{11}{16}$	35.1252	21.0094	$\frac{1}{8}$	65.3968	28.6671
$\frac{3}{4}$	35.7847	21.2058	$\frac{3}{16}$	66.2957	28.8634
$\frac{13}{16}$	36.4505	21.4021	$\frac{1}{4}$	67.2007	29.0598
$\frac{7}{8}$	37.1224	21.5985	$\frac{5}{16}$	68.1120	29.2561
$\frac{15}{16}$	37.8005	21.7948	$\frac{3}{8}$	69.0293	29.4525
			$\frac{7}{16}$	69.9528	29.6488

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
½	70.8823	29.8452	12 in.	113.0976	37.6992
$\frac{9}{16}$	71.8181	30.0415	$\frac{1}{16}$	114.2788	37.8955
⅝	72.7599	30.2379	⅛	115.4660	38.0919
$\frac{11}{16}$	73.7079	30.4342	$\frac{3}{16}$	116.6645	38.2882
¾	74.6620	30.6306	¼	117.8590	38.4846
$\frac{13}{16}$	75.6223	30.8269	$\frac{5}{16}$	119.0648	38.6809
⅞	76.5887	31.0233	⅜	120.2766	38.8773
$\frac{15}{16}$	77.5613	31.2196	$\frac{7}{16}$	121.4946	39.0736
			½	122.7187	39.2700
10 in.	78.5400	31.4160	$\frac{9}{16}$	123.9490	39.4663
$\frac{1}{16}$	79.5248	31.6123	⅝	125.1854	39.6627
⅛	80.5157	31.8087	$\frac{11}{16}$	126.4479	39.8590
$\frac{3}{16}$	81.5128	32.0050	¾	127.6765	40.0554
¼	82.5160	32.2014	$\frac{13}{16}$	128.8999	40.2517
$\frac{5}{16}$	83.5254	32.3977	⅞	130.1923	40.4481
⅜	84.5409	32.5941	$\frac{15}{16}$	131.4279	40.6444
$\frac{7}{16}$	85.5626	32.7904			
½	86.5903	32.9868	13 in.	132.7326	40.8408
$\frac{9}{16}$	87.6243	33.1831	$\frac{1}{16}$	134.0120	41.0371
⅝	88.6643	33.3795	⅛	135.2974	41.2338
$\frac{11}{16}$	89.7105	33.5758	$\frac{3}{16}$	136.5890	41.4298
¾	90.7627	33.7722	¼	137.8867	41.6262
$\frac{13}{16}$	91.8212	33.9685	$\frac{5}{16}$	139.1907	41.8225
⅞	92.8858	34.1649	⅜	140.5007	42.0189
$\frac{15}{16}$	93.9566	34.3612	$\frac{7}{16}$	141.8169	42.2152
			½	143.1391	42.4116
11 in.	95.0334	34.5596	$\frac{9}{16}$	144.4726	42.6079
$\frac{1}{16}$	96.1164	34.7539	⅝	145.8021	42.8043
⅛	97.2053	34.9503	$\frac{11}{16}$	147.1428	43.0006
$\frac{3}{16}$	98.3008	35.1466	¾	148.4896	43.1970
¼	99.4021	35.3430	$\frac{13}{16}$	149.8426	43.3933
$\frac{5}{16}$	100.5097	35.5393	⅞	151.2017	43.5897
⅜	101.6234	35.7357	$\frac{15}{16}$	152.5670	43.7860
$\frac{7}{16}$	102.7432	35.9320			
½	103.8691	36.1284	14 in.	153.9384	43.9824
$\frac{9}{16}$	105.0012	36.3247	$\frac{1}{16}$	155.3159	44.1787
⅝	106.1394	36.5211	⅛	156.6995	44.3751
$\frac{11}{16}$	107.2838	36.7174	$\frac{3}{16}$	158.0893	44.5714
¾	108.4342	36.9138	¼	159.4852	44.7676
$\frac{13}{16}$	109.5909	37.1101	$\frac{5}{16}$	160.8374	44.9641
⅞	110.7536	37.3065	⅜	162.2956	45.1605
$\frac{15}{16}$	111.9226	37.5028	$\frac{7}{16}$	163.7099	45.3568

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	165.1303	45.5532	17 in.	226.9806	53.4072
9/16	166.5569	45.7495	1/16	228.6527	53.6035
5/8	167.9896	45.9459	1/8	230.3308	53.7999
11/16	169.4285	46.1422	3/16	232.0151	53.9962
3/4	170.8735	46.3386	1/4	233.7055	54.1926
13/16	172.3247	46.5349	5/16	235.4022	54.3889
7/8	173.7820	46.7313	3/8	237.1049	54.5853
15/16	175.2455	46.9276	7/16	238.8138	54.7816
			1/2	240.5287	54.9780
15 in.	176.7150	47.1240	9/16	242.2499	55.1743
1/16	178.1907	47.3203	5/8	243.9771	55.3707
1/8	179.6725	47.5167	11/16	245.7105	55.5670
3/16	181.1105	47.7130	3/4	247.4500	55.7634
1/4	182.6545	47.9094	13/16	249.1952	55.9597
5/16	184.1548	48.1057	7/8	250.9475	56.1561
3/8	185.6612	48.3021	15/16	252.7050	56.3524
7/16	187.1737	48.4984			
1/2	188.6923	48.6948	18 in.	254.4696	56.5488
9/16	190.2171	48.8911	1/16	256.2398	56.7451
5/8	191.7480	49.0875	1/8	258.0161	56.9415
11/16	193.3351	49.2838	3/16	259.7986	57.1378
3/4	194.8282	49.4802	1/4	261.5872	57.3342
13/16	196.3776	49.6765	5/16	263.3820	57.5305
7/8	197.9330	49.8729	3/8	265.1829	57.7269
15/16	199.4947	50.0692	7/16	266.9900	57.9282
			1/2	268.8031	58.1196
16 in.	201.0624	50.2656	9/16	270.6225	58.2159
1/16	202.6363	50.4619	5/8	272.4479	58.5123
1/8	204.2162	50.6583	11/16	274.2895	58.7806
3/16	205.8024	50.8546	3/4	276.1171	58.9056
1/4	207.3946	51.0510	13/16	277.9610	59.1013
5/16	208.9931	51.2473	7/8	279.8110	59.2977
3/8	210.5976	51.4437	15/16	281.1672	59.4940
7/16	212.2083	51.6400			
1/2	213.8251	51.8364	19 in.	283.5294	59.6904
9/16	215.4481	52.0327	1/16	285.3978	59.8867
5/8	217.0772	52.2291	1/8	287.2723	60.0831
11/16	218.7124	52.4254	3/16	289.4030	60.2794
3/4	220.3537	52.6218	1/4	291.0397	60.4758
13/16	222.0013	52.8181	5/16	292.9324	60.6721
7/8	223.6549	53.0145	3/8	294.8312	60.8685
15/16	225.3147	53.2108	7/16	296.7367	61.0648

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	298.6483	61.2612	22 in.	380.1336	69.1152
9/16	300.5658	61.4575	1/16	382.2965	69.3115
5/8	302.4894	61.6539	1/8	384.4655	69.5079
11/16	304.4192	61.8502	3/16	386.6907	69.7042
3/4	306.3550	62.0466	1/4	388.8220	69.9006
13/16	308.2971	62.2429	5/16	391.0095	70.0969
7/8	310.2452	62.4393	3/8	393.2031	70.2933
15/16	312.1996	62.6356	7/16	395.4029	70.4806
			1/2	397.6087	70.6860
20 in.	314.1600	62.8320	9/16	399.8207	70.8823
1/16	316.1266	63.0283	5/8	402.0388	71.0787
1/8	318.0992	63.2247	11/16	404.2631	71.2750
3/16	320.0781	63.4210	3/4	406.4935	71.4714
1/4	322.0630	63.6174	13/16	408.7301	71.6677
5/16	324.0542	63.8137	7/8	410.9728	71.8641
3/8	326.0514	64.0101	15/16	413.2317	72.0604
7/16	328.0548	64.2064			
1/2	330.0643	64.4028	23 in.	415.4766	72.2568
9/16	332.0800	64.5991	1/16	417.7377	72.4531
5/8	334.1018	64.7955	1/8	420.0049	72.6495
11/16	336.1297	64.9918	3/16	422.2783	72.8458
3/4	338.1637	65.1882	1/4	424.5577	73.0422
13/16	340.2040	65.3845	5/16	426.3434	73.2385
7/8	342.2502	65.5809	3/8	429.1352	73.4349
15/16	344.3028	65.7772	7/16	431.4331	73.6312
			1/2	433.7371	73.8276
21 in.	346.3614	65.7936	9/16	436.0473	74.0239
1/16	348.4267	66.1699	5/8	438.3636	74.2203
1/8	350.4970	66.3663	11/16	440.6811	74.4166
3/16	352.5740	66.5626	3/4	443.0146	74.6130
1/4	354.6571	66.7590	13/16	445.3539	74.8093
5/16	356.7465	66.9553	7/8	447.6992	75.0057
3/8	358.8419	67.1517	15/16	450.0418	75.2020
7/16	360.9435	67.3480			
1/2	363.0511	67.5444	24 in.	452.3904	75.3984
9/16	365.1650	67.7407	1/16	454.7497	75.5947
5/8	367.2849	67.9371	1/8	457.1150	75.7911
11/16	369.4110	68.1334	3/16	459.4866	75.9874
3/4	371.5432	68.3298	1/4	461.8642	76.1838
13/16	373.6816	68.5261	5/16	464.2481	76.3801
7/8	375.8261	68.7225	3/8	466.6380	76.5765
15/16	377.9768	68.9188	7/16	469.0341	76.7728

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
$\frac{1}{2}$	471.4363	76.9692	27 in.	572.5566	84.8232
$\frac{9}{16}$	473.8447	77.1655	$\frac{1}{16}$	575.2104	85.0195
$\frac{5}{8}$	476.2592	77.3619	$\frac{1}{8}$	577.8703	85.2159
$\frac{11}{16}$	478.6798	77.5582	$\frac{3}{16}$	580.5364	85.4122
$\frac{3}{4}$	481.1065	77.7546	$\frac{1}{4}$	583.2085	85.6086
$\frac{13}{16}$	483.5395	77.9509	$\frac{5}{16}$	585.8869	85.8049
$\frac{7}{8}$	485.9785	78.1473	$\frac{3}{8}$	588.5714	86.0013
$\frac{15}{16}$	488.4237	78.3436	$\frac{7}{16}$	591.2620	86.1976
			$\frac{1}{2}$	593.9587	86.3940
25 in.	490.8750	78.5400	$\frac{9}{16}$	596.6616	86.5903
$\frac{1}{16}$	493.3325	78.7363	$\frac{5}{8}$	599.3706	86.7867
$\frac{1}{8}$	495.7960	78.9327	$\frac{11}{16}$	602.0858	86.9830
$\frac{3}{16}$	498.2657	79.1290	$\frac{3}{4}$	604.8070	87.1794
$\frac{1}{4}$	500.7415	79.3254	$\frac{13}{16}$	607.5345	87.3757
$\frac{5}{16}$	503.2236	79.5217	$\frac{7}{8}$	610.2680	87.5721
$\frac{3}{8}$	505.7117	79.7181	$\frac{15}{16}$	613.0078	87.7684
$\frac{7}{16}$	508.2060	79.9144			
$\frac{1}{2}$	510.7063	80.1108	28 in.	615.7536	87.9648
$\frac{9}{16}$	513.2129	80.3071	$\frac{1}{16}$	618.5051	88.1611
$\frac{5}{8}$	515.7255	80.5035	$\frac{1}{8}$	621.2636	88.3575
$\frac{11}{16}$	518.2443	80.6998	$\frac{3}{16}$	624.0279	88.5538
$\frac{3}{4}$	520.7692	80.8962	$\frac{1}{4}$	626.7982	88.7502
$\frac{13}{16}$	523.3003	81.0925	$\frac{5}{16}$	629.5748	88.9465
$\frac{7}{8}$	525.8375	81.2889	$\frac{3}{8}$	632.3574	89.1429
$\frac{15}{16}$	528.3809	81.4852	$\frac{7}{16}$	635.1462	89.3392
			$\frac{1}{2}$	637.9411	89.5356
26 in.	530.9304	81.6816	$\frac{9}{16}$	640.7422	89.7319
$\frac{1}{16}$	533.4860	81.8779	$\frac{5}{8}$	643.5494	89.9283
$\frac{1}{8}$	536.0477	82.0743	$\frac{11}{16}$	646.3627	90.1246
$\frac{3}{16}$	538.6156	82.2706	$\frac{3}{4}$	649.1821	90.3210
$\frac{1}{4}$	541.1896	82.4670	$\frac{13}{16}$	652.0078	90.5173
$\frac{5}{16}$	543.7698	82.6633	$\frac{7}{8}$	654.8395	90.7137
$\frac{3}{8}$	546.3561	82.8597	$\frac{15}{16}$	657.6774	90.9100
$\frac{7}{16}$	548.9486	83.0560			
$\frac{1}{2}$	551.5471	83.2524	29 in.	660.5214	91.1064
$\frac{9}{16}$	554.1519	83.4487	$\frac{1}{16}$	663.3716	91.3027
$\frac{5}{8}$	556.7627	83.6451	$\frac{1}{8}$	666.2278	91.4991
$\frac{11}{16}$	559.3797	83.8414	$\frac{3}{16}$	669.0902	91.6954
$\frac{3}{4}$	562.0027	84.0378	$\frac{1}{4}$	671.9587	91.8918
$\frac{13}{16}$	564.6320	84.2341	$\frac{5}{16}$	674.8335	92.0081
$\frac{7}{8}$	567.2674	84.4305	$\frac{3}{8}$	677.7143	92.2845
$\frac{15}{16}$	569.4090	84.6268	$\frac{7}{16}$	680.6013	92.4808

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	683.4943	92.6772	32 in.	804.2496	100.5312
9/16	686.3936	92.8735	1/16	807.3943	100.7275
5/8	689.2989	93.0699	1/8	810.5450	100.9240
11/16	692.2104	93.2662	3/16	813.7020	101.1202
3/4	695.1280	93.4626	1/4	816.8650	101.3166
13/16	698.0518	93.6589	5/16	820.0343	101.5130
7/8	700.9817	93.8553	3/8	823.2096	101.7093
15/16	703.9178	94.0516	7/16	826.3911	101.9056
			1/2	829.5787	102.1020
30 in.	706.8600	94.2480	9/16	832.7725	102.2983
1/16	709.8083	94.4443	5/8	835.9724	102.4947
1/8	712.7627	94.6407	11/16	839.1784	102.6910
3/16	715.7233	94.8370	3/4	842.3905	102.8874
1/4	718.6900	95.0334	13/16	845.6089	103.0837
5/16	721.6629	95.2297	7/8	848.8333	103.2801
3/8	724.6419	95.4261	15/16	852.0639	103.4764
7/16	727.6271	95.6224			
1/2	730.6183	95.8188	33 in.	855.3006	103.6728
9/16	733.6158	96.0151	1/16	858.5436	103.8691
5/8	736.6193	96.2115	1/8	861.7924	104.0655
11/16	739.6290	96.4078	3/16	865.0475	104.2618
3/4	742.6447	96.6042	1/4	868.3087	104.4582
13/16	745.6667	96.8005	5/16	871.5760	104.6545
7/8	748.6948	96.9969	3/8	874.8497	104.8509
15/16	751.7291	97.1932	7/16	878.1290	105.0472
			1/2	881.4151	105.2436
31 in.	754.7694	97.3896	9/16	884.7070	105.4399
1/16	757.8159	97.5859	5/8	888.0051	105.6363
1/8	760.8685	97.7823	11/16	891.3090	105.8326
3/16	763.9273	97.9786	3/4	894.6196	106.0290
1/4	766.9921	98.1750	13/16	897.9369	106.2253
5/16	770.0632	98.3713	7/8	901.2587	106.4217
3/8	773.1404	98.5677	15/16	904.5875	106.6180
7/16	776.2237	98.7648			
1/2	779.3131	98.9684	34 in.	907.9224	106.8144
9/16	782.4087	99.1567	1/16	911.2645	107.0107
5/8	785.5104	99.3531	1/8	914.6105	107.2071
11/16	788.6183	99.5494	3/16	917.9640	107.4034
3/4	791.7322	99.7458	1/4	921.3232	107.5998
13/16	794.8524	99.9421	5/16	924.6883	107.7961
7/8	797.9786	100.1385	3/8	928.0605	107.9925
15/16	801.1111	100.3348	7/16	931.4380	108.1888

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	934.8223	108.3852	37 in.	1075.2126	116.2392
9/16	938.2121	108.5815	1/16	1078.8482	116.4355
5/8	941.6087	108.7779	1/8	1082.4898	116.6319
11/16	945.0110	108.9742	3/16	1086.1376	116.8282
3/4	948.4195	109.1706	1/4	1089.7915	117.0246
13/16	951.8341	109.3669	5/16	1093.4517	117.2209
7/8	955.2550	109.5633	3/8	1097.1179	117.4173
15/16	958.6820	109.7596	7/16	1100.7903	117.6136
			1/2	1104.4687	117.8100
35 in.	962.1150	109.9560	9/16	1108.1534	118.0063
1/16	965.5542	110.1523	5/8	1111.8441	118.2027
1/8	968.9995	110.3487	11/16	1115.5410	118.3990
3/16	972.4510	110.5450	3/4	1119.2440	118.5954
1/4	975.9085	110.7414	13/16	1122.9532	118.7917
5/16	979.3686	110.9377	7/8	1126.6685	118.9881
3/8	982.8422	111.1341	15/16	1130.3900	119.1844
7/16	986.3180	111.3304			
1/2	989.8003	111.5268	38 in.	1134.1176	119.3808
9/16	993.2097	111.7231	1/16	1137.8513	119.5771
5/8	996.7830	111.9195	1/8	1141.5911	119.7735
11/16	1000.3472	112.1158	3/16	1145.3371	119.9698
3/4	1003.7902	112.3122	1/4	1149.0892	120.1662
13/16	1007.3030	112.5086	5/16	1152.8475	120.3625
7/8	1010.8220	112.7049	3/8	1156.6119	120.5589
15/16	1014.3472	112.9012	7/16	1160.3825	120.7552
			1/2	1164.1591	120.9516
36 in.	1017.8784	113.0976	9/16	1167.9420	121.1479
1/16	1021.4158	113.2939	5/8	1171.7309	121.3443
1/8	1024.9592	113.4903	11/16	1175.5260	121.5406
3/16	1028.5089	113.6866	3/4	1179.3271	121.7370
1/4	1032.0646	113.8830	13/16	1183.1345	121.9333
5/16	1035.6266	114.0793	7/8	1186.9480	122.1297
3/8	1039.1946	114.2757	15/16	1190.7677	122.3260
7/16	1042.7913	114.4720			
1/2	1046.3941	114.6684	39 in.	1194.5934	122.5224
9/16	1049.9581	114.8647	1/16	1198.4253	122.7187
5/8	1053.5281	115.0611	1/8	1202.2633	122.9151
11/16	1057.1269	115.2572	3/16	1206.1075	123.1114
3/4	1060.7317	115.4538	1/4	1209.9577	123.3078
13/16	1064.3428	115.6501	5/16	1213.8142	123.5041
7/8	1067.9599	115.8465	3/8	1217.6768	123.7005
15/16	1071.5832	116.0428	7/16	1221.5455	123.8968

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
½	1225.4203	124.0932	42 in.	1385.4456	131.9472
9/16	1229.3013	124.2895	1/16	1389.5720	132.1435
5/8	1233.1884	124.4859	1/8	1393.7045	132.3399
11/16	1237.0817	124.6822	3/16	1397.8432	132.5362
¾	1240.9810	124.8786	¼	1401.9880	132.7326
13/16	1244.8866	125.0749	5/16	1406.1390	132.9289
7/8	1248.7982	125.2713	3/8	1410.2961	133.1253
15/16	1252.7161	125.4676	7/16	1414.4594	133.3216
			½	1418.6287	133.5180
40 in.	1256.6400	125.6640	9/16	1422.8043	133.7143
1/16	1260.5701	125.8603	5/8	1426.9859	133.9107
1/8	1264.5062	126.0567	11/16	1431.1737	134.1070
3/16	1268.4486	126.2530	¾	1435.3675	134.3034
¼	1272.3970	126.4494	13/16	1439.5676	134.4997
5/16	1276.3517	126.6457	7/8	1443.7738	134.6961
3/8	1280.3124	126.8421	15/16	1447.9862	134.8924
7/16	1284.2793	127.0384			
½	1288.2523	127.2348	43 in.	1452.2046	135.0888
9/16	1292.2315	127.4311	1/16	1456.4292	135.2851
5/8	1296.2168	127.6275	1/8	1460.6599	135.4815
11/16	1300.2082	127.8238	3/16	1464.8968	135.6778
¾	1304.2057	128.0202	¼	1469.1397	135.8742
13/16	1308.2095	128.2165	5/16	1473.3839	136.0705
7/8	1312.2193	128.4129	3/8	1477.6342	136.2669
15/16	1316.2353	128.6092	7/16	1481.9006	136.4632
			½	1486.1731	136.6596
41 in.	1320.2574	128.8056	9/16	1490.4468	136.8559
1/16	1324.2857	129.0019	5/8	1494.7266	137.0523
1/8	1328.3200	129.1983	11/16	1499.0126	137.2486
3/16	1332.3605	129.3946	¾	1503.3046	137.4450
¼	1336.4071	129.5910	13/16	1507.6029	137.6413
5/16	1340.4600	129.7873	7/8	1511.9072	137.8377
3/8	1344.5189	129.9837	15/16	1516.2178	138.0340
7/16	1348.5840	130.1800			
½	1352.6551	130.3764	44 in.	1520.5344	138.2304
9/16	1356.7325	130.5727	1/16	1524.8572	138.4267
5/8	1360.8159	130.7691	1/8	1529.1860	138.6231
11/16	1364.9055	130.9654	3/16	1533.5211	138.8194
¾	1369.0012	131.1618	¼	1537.8622	139.0158
13/16	1373.1031	131.3581	5/16	1542.2046	139.2121
7/8	1377.2111	131.5545	3/8	1546.5530	139.4085
15/16	1381.3253	131.7508	7/16	1550.9176	139.6048

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	1555.2883	139.8012	47 in.	1734.9486	147.6552
9/16	1559.6602	139.9975	1/16	1739.5659	147.8515
5/8	1564.0382	140.1939	1/8	1744.1893	148.0479
11/16	1568.4223	140.3902	3/16	1748.8189	148.2442
3/4	1572.8125	140.5866	1/4	1753.4545	148.4406
13/16	1577.2090	140.7829	5/16	1758.0914	148.6369
7/8	1581.6115	140.9793	3/8	1762.7344	148.8333
15/16	1586.0203	141.1756	7/16	1767.3935	149.0296
			1/2	1772.0587	149.2260
45 in.	1590.4350	141.3720	9/16	1776.7251	149.4223
1/16	1594.4560	141.5683	5/8	1781.3976	149.6187
1/8	1599.2830	141.7647	11/16	1786.0763	149.8150
3/16	1603.7162	141.9610	3/4	1790.7610	150.0114
1/4	1608.1555	142.1574	13/16	1795.4520	150.2077
5/16	1612.5961	142.3537	7/8	1800.1490	150.4041
3/8	1617.0427	142.5501	15/16	1804.8523	150.6004
7/16	1621.5055	142.7464			
1/2	1625.9743	142.9428	48 in.	1809.5616	150.7968
9/16	1630.4444	143.1391	1/16	1814.2551	150.9931
5/8	1634.9205	143.3355	1/8	1818.9986	151.1895
11/16	1639.4028	143.5318	3/16	1823.7264	151.3858
3/4	1643.8912	143.7282	1/4	1828.4602	151.5822
13/16	1648.3858	143.9245	5/16	1833.1953	151.7785
7/8	1652.8865	144.1209	3/8	1837.9364	151.9749
15/16	1657.3934	144.3172	7/16	1842.6937	152.1712
			1/2	1847.4571	152.3676
46 in.	1661.9064	144.5136	9/16	1852.2167	152.5639
1/16	1666.4255	144.7099	5/8	1856.9924	152.7603
1/8	1670.9507	144.9063	11/16	1861.7892	152.9566
3/16	1675.4821	145.1026	3/4	1868.5521	153.1530
1/4	1680.0196	145.2990	13/16	1871.3413	153.3493
5/16	1684.5583	145.4953	7/8	1876.1365	153.5457
3/8	1689.1031	145.6917	15/16	1880.9379	153.7420
7/16	1693.6641	145.8880			
1/2	1698.2311	146.0844	49 in.	1885.7454	153.9384
9/16	1702.7994	146.2807	1/16	1890.5591	154.1347
5/8	1707.3737	146.4771	1/8	1895.3788	154.3311
11/16	1711.9542	146.6734	3/16	1900.2047	154.5274
3/4	1716.5407	146.8698	1/4	1905.0367	154.7238
13/16	1721.1335	147.0661	5/16	1909.8700	154.9201
7/8	1725.7324	147.2625	3/8	1914.7093	155.1165
15/16	1730.3375	147.4588	7/16	1919.5648	155.3128

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	1924.4263	155.5092	52 in.	2123.7216	163.3632
9/16	1929.2891	155.7055	1/16	2128.8298	163.5595
5/8	1934.1579	155.9019	1/8	2133.9440	163.7559
11/16	1939.0329	156.0982	3/16	2139.0645	163.9522
3/4	1943.9140	156.2946	1/4	2144.1910	164.1486
13/16	1948.8013	156.4909	5/16	2149.3238	164.3449
7/8	1953.6947	156.6873	3/8	2154.4626	164.5413
15/16	1958.0943	156.8836	7/16	2159.6076	164.7376
			1/2	2164.7587	164.9340
50 in.	1963.5000	157.0800	9/16	2169.9160	165.1303
1/16	1968.4118	157.2763	5/8	2175.0794	165.3267
1/8	1973.3297	157.4727	11/16	2180.2489	165.5230
3/16	1978.2525	157.6690	3/4	2185.4245	165.7194
1/4	1983.1840	157.8654	13/16	2190.6064	165.9157
5/16	1988.6154	158.0617	7/8	2195.7943	166.1121
3/8	1993.0529	158.2581	15/16	2200.9884	166.3084
7/16	1998.0066	158.4544			
1/2	2002.9663	158.6508	53 in.	2206.1886	166.5048
9/16	2007.9273	158.8471	1/16	2211.3950	166.7011
5/8	2012.8943	159.0435	1/8	2216.6074	166.8975
11/16	2017.8675	159.2398	3/16	2221.8260	167.0938
3/4	2022.8467	159.4362	1/4	2227.0507	167.2902
13/16	2027.8172	159.6325	5/16	2232.2817	167.4865
7/8	2032.8238	159.8289	3/8	2237.5187	167.6829
15/16	2037.8216	160.0252	7/16	2242.7619	167.8792
			1/2	2248.0111	168.0756
51 in.	2042.8254	160.2216	9/16	2253.2666	168.2719
1/16	2047.8354	160.4179	5/8	2258.5281	168.4683
1/8	2052.8515	160.6143	11/16	2263.7908	168.6646
3/16	2057.8798	160.8106	3/4	2269.0696	168.8610
1/4	2062.9021	161.0070	13/16	2274.3496	169.0573
5/16	2067.9317	161.2033	7/8	2279.6357	169.2537
3/8	2072.9674	161.3997	15/16	2284.9280	169.4500
7/16	2078.0293	161.5960			
1/2	2083.0771	161.7924	54 in.	2290.2264	169.6464
9/16	2088.1362	161.9887	1/16	2295.5309	169.8427
5/8	2093.2014	162.1851	1/8	2300.8415	170.0391
11/16	2098.2678	162.3814	3/16	2306.1583	170.2354
3/4	2103.3502	162.5778	1/4	2311.4812	170.4318
13/16	2108.4339	162.7741	5/16	2316.8163	170.6281
7/8	2113.5236	162.9705	3/8	2322.1455	170.8245
15/16	2118.1196	163.1668	7/16	2327.4819	171.0208

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	2332.8343	171.2172	57 in.	2551.7646	179.0712
9/16	2338.1880	171.4135	1/16	2557.3637	179.2675
5/8	2343.5477	171.6099	1/8	2562.9688	179.4639
11/16	2348.9636	171.8062	3/16	2568.5801	179.6602
3/4	2354.2855	172.0026	1/4	2574.1975	179.8566
13/16	2359.6637	172.1989	5/16	2579.8212	180.0529
7/8	2365.0480	172.3953	3/8	2585.4509	180.2493
15/16	2370.4385	172.5916	7/16	2591.0869	180.4456
			1/2	2596.7287	180.6420
55 in.	2375.8350	172.7880	9/16	2602.3769	180.8383
1/16	2381.2382	172.9843	5/8	2608.0311	181.0347
1/8	2386.6465	173.1807	11/16	2613.6942	181.2310
3/16	2392.0515	173.3770	3/4	2619.3580	181.4274
1/4	2397.4825	173.5734	13/16	2625.0307	181.6237
5/16	2402.9098	173.7697	7/8	2630.7095	181.8201
3/8	2408.3432	173.9661	15/16	2636.3945	182.0164
7/16	2413.7777	174.1624			
1/2	2419.2283	174.3588	58 in.	2642.0856	182.2128
9/16	2424.7026	174.5551	1/16	2647.7328	182.4091
5/8	2430.1830	174.7515	1/8	2653.4861	182.6055
11/16	2435.6246	174.9478	3/16	2659.9565	182.8018
3/4	2441.0722	175.1442	1/4	2664.9112	182.9982
13/16	2446.5486	175.3405	5/16	2670.6330	183.1945
7/8	2452.0310	175.5369	3/8	2676.3609	183.3909
15/16	2457.0197	175.7332	7/16	2682.0950	183.5872
			1/2	2687.8351	183.7836
56 in.	2463.0144	175.9296	9/16	2693.5814	183.9799
1/16	2468.5153	176.1259	5/8	2699.3338	184.1763
1/8	2474.0222	176.3223	11/16	2705.0924	184.3726
3/16	2479.5354	176.5186	3/4	2710.8571	184.5690
1/4	2485.0546	176.7150	13/16	2716.6280	184.7653
5/16	2490.5351	176.9913	7/8	2722.4050	184.9617
3/8	2496.1116	177.1077	15/16	2728.1882	185.1580
7/16	2501.6493	177.3040			
1/2	2507.1931	177.5004	59 in.	2733.9774	185.3544
9/16	2512.7431	177.6967	1/16	2739.7728	185.5507
5/8	2518.2992	177.8931	1/8	2745.5743	185.7471
11/16	2523.8614	178.0894	3/16	2751.8820	185.9434
3/4	2529.4297	178.2858	1/4	2757.1957	186.1398
13/16	2535.0043	178.4821	5/16	2763.0157	186.3361
7/8	2540.5849	178.6785	3/8	2768.8418	186.5325
15/16	2546.1717	178.8748	7/16	2774.6745	186.7288

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	2780.5123	186.9252	62 in.	3019.0776	194.7792
9/16	2786.3568	187.1215	1/16	3025.1675	194.9755
5/8	2792.2074	187.3179	1/8	3031.2635	195.1719
11/16	2798.0642	187.5142	3/16	3037.3607	195.3682
3/4	2803.9270	187.7106	1/4	3043.4740	195.5646
13/16	2809.7461	187.9069	5/16	3049.6885	195.7609
7/8	2815.6712	188.1033	3/8	3055.7091	195.9573
15/16	2821.5526	188.2996	7/16	3061.8359	196.1536
			1/2	3067.9687	196.3500
60 in.	2827.4400	188.4960	9/16	3074.1578	196.5463
1/16	2833.3336	188.6923	5/8	3080.2529	196.7427
1/8	2839.2332	188.8887	11/16	3086.4042	196.9390
3/16	2845.1391	189.0850	3/4	3092.5615	197.1354
1/4	2851.0510	189.2814	13/16	3098.7251	197.3317
5/16	2856.9692	189.4777	7/8	3104.8948	197.5281
3/8	2862.8934	189.6741	15/16	3111.0707	197.7244
7/16	2868.8223	189.8704			
1/2	2874.7603	189.0668	63 in.	3117.2526	197.9208
9/16	2880.7030	190.2631	1/16	3124.4407	198.1171
5/8	2886.6517	190.4595	1/8	3129.6349	198.3135
11/16	2892.6067	190.6558	3/16	3135.8353	198.5098
3/4	2898.5677	190.8522	1/4	3142.0417	198.7062
13/16	2904.5350	191.0485	5/16	3148.7544	198.9025
7/8	2910.5083	191.2449	3/8	3154.4732	199.0989
15/16	2916.4878	191.4412	7/16	3160.7981	199.2952
			1/2	3166.9291	199.4916
61 in.	2922.4734	191.6376	9/16	3173.1663	199.6879
1/16	2928.4652	191.8339	5/8	3179.4096	199.8843
1/8	2934.4630	192.0303	11/16	3185.6591	200.0806
3/16	2940.4670	192.2266	3/4	3191.9146	200.2770
1/4	2946.4771	192.4230	13/16	3193.1764	200.4733
5/16	2952.4938	192.6193	7/8	3204.4442	200.6697
3/8	2958.5159	192.8157	15/16	3210.7183	200.8660
7/16	2964.5445	193.0120			
1/2	2970.5791	193.2084	64 in.	3216.9984	201.0624
9/16	2976.6200	193.4047	1/16	3223.2847	201.2587
5/8	2982.6669	193.6011	1/8	3229.5770	201.4551
11/16	2988.7200	193.7974	3/16	3235.8746	201.6514
3/4	2994.7792	193.9938	1/4	3242.1782	201.8478
13/16	3000.8423	194.1901	5/16	3248.4936	202.0441
7/8	3006.9161	194.3865	3/8	3254.8080	202.2405
15/16	3017.9938	194.5828	7/16	3261.1311	202.4368

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	3267.4603	202.6332	67 in.	3525.6606	210.4872
9/16	3273.7957	202.8295	1/16	3532.2414	210.6835
5/8	3280.1372	203.0259	1/8	3538.8283	210.8799
11/16	3286.4875	203.2222	3/16	3545.4200	211.0762
3/4	3292.8385	203.4186	1/4	3552.0185	211.2726
13/16	3299.1985	203.6149	5/16	3558.6249	211.4689
7/8	3305.5645	203.8113	3/8	3565.2374	211.6653
15/16	3311.9367	204.0076	7/16	3571.8550	211.8616
			1/2	3578.4787	212.0580
65 in.	3318.3151	204.2040	9/16	3585.1086	212.2543
1/16	3324.7495	204.4003	5/8	3591.7446	212.4507
1/8	3331.0900	204.5917	11/16	3598.3868	212.6470
3/16	3337.9857	204.7930	3/4	3605.0350	212.8434
1/4	3343.8875	204.9894	13/16	3611.6895	213.0397
5/16	3350.2976	205.1857	7/8	3618.3500	213.2361
3/8	3356.7137	205.3821	15/16	3625.0168	213.4324
7/16	3363.1350	205.5784			
1/2	3369.5623	205.7748	68 in.	3631.6896	213.6288
9/16	3375.9959	205.9711	1/16	3638.3686	213.8251
5/8	3382.4355	206.1675	1/8	3645.0536	214.0215
11/16	3388.8813	206.3638	3/16	3651.7439	214.2178
3/4	3395.3332	206.5602	1/4	3658.4402	214.4142
13/16	3401.7913	206.7565	5/16	3665.1448	214.6105
7/8	3408.2555	206.9529	3/8	3671.8554	214.8069
15/16	3414.7259	207.1492	7/16	3678.5762	215.0032
			1/2	3685.2931	215.1996
66 in.	3421.2024	207.3456	9/16	3692.0212	215.3959
1/16	3427.6850	207.5419	5/8	3698.7554	215.5923
1/8	3434.1737	207.7383	11/16	3703.9957	215.7886
3/16	3440.6676	207.9346	3/4	3712.2421	215.9850
1/4	3447.1676	208.1310	13/16	3718.9948	216.1813
5/16	3453.6758	208.3273	7/8	3725.7535	216.3777
3/8	3468.1901	208.5237	15/16	3732.5184	216.5748
7/16	3470.7096	208.7200			
1/2	3473.2351	208.9164	69 in.	3739.2894	216.7704
9/16	3479.7669	209.1127	1/16	3745.8166	216.9667
5/8	3486.3047	209.3091	1/8	3752.8498	217.1631
11/16	3492.8487	209.5054	3/16	3759.6382	217.3594
3/4	3499.3987	209.7018	1/4	3766.4327	217.5558
13/16	3506.4550	209.8981	5/16	3773.2355	217.7521
7/8	3512.5174	210.0945	3/8	3780.0443	217.9485
15/16	3519.0860	210.2908	7/16	3786.8628	218.1448

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	3793.6783	218.3412	72 in.	4071.5136	226.1952
9/16	3800.5191	218.5375	1/16	4078.5853	226.3915
5/8	3807.3369	218.7339	1/8	4085.6631	226.5879
11/16	3814.2781	218.9302	3/16	4092.7460	226.7842
3/4	3821.0200	219.1266	1/4	4099.8350	226.9806
13/16	3827.8708	219.3229	5/16	4106.9323	227.1769
7/8	3834.7277	219.5193	3/8	4114.0356	227.3733
15/16	3841.5908	219.7156	7/16	4121.1442	227.5696
			1/2	4128.2587	227.7660
70 in.	3848.4600	219.9120	9/16	4135.3795	227.9623
1/16	3855.8353	220.1083	5/8	4142.5064	228.1587
1/8	3862.2167	220.3047	11/16	4149.6394	228.3550
3/16	3869.1033	220.5010	3/4	4156.7785	228.5514
1/4	3875.9960	220.6974	13/16	4163.9239	228.7477
5/16	3882.8969	220.8937	7/8	4171.0753	228.9441
3/8	3889.8039	221.0901	15/16	4178.2329	229.1404
7/16	3896.7211	221.2864			
1/2	3903.6343	221.4828	73 in.	4185.3966	229.3368
9/16	3910.5588	221.6791	1/16	4192.5665	229.5331
5/8	3917.4893	221.8755	1/8	4199.7424	229.7295
11/16	3924.4260	222.0718	3/16	4206.9230	229.9258
3/4	3931.3687	222.2682	1/4	4214.1107	230.1222
13/16	3938.3177	222.4645	5/16	4221.3027	230.3185
7/8	3945.2728	222.6609	3/8	4228.5077	230.5149
15/16	3952.2341	222.8572	7/16	4235.7109	230.7112
			1/2	4242.9271	230.9076
71 in.	3959.2014	223.0536	9/16	4250.1461	231.1039
1/16	3966.1749	223.2499	5/8	4257.3711	231.3003
1/8	3973.1545	223.4463	11/16	4264.6023	231.4966
3/16	3980.1393	223.6426	3/4	4271.8396	231.6930
1/4	3987.1301	223.8390	13/16	4279.0831	231.8893
5/16	3994.1292	224.0353	7/8	4286.3327	232.0857
3/8	4001.1344	224.2317	15/16	4293.5885	232.2820
7/16	4008.1447	224.4380			
1/2	4015.1611	224.6244	74 in.	4300.8504	232.4784
9/16	4022.1837	224.8207	1/16	4308.1185	232.6747
5/8	4029.2124	225.0171	1/8	4315.3926	232.8711
11/16	4036.2473	225.2134	3/16	4322.1719	233.0674
3/4	4043.2882	225.4098	1/4	4329.9572	233.2638
13/16	4050.3354	225.6061	5/16	4337.2508	233.4601
7/8	4057.3886	225.8025	3/8	4344.5505	233.6565
15/16	4064.4481	225.9988	7/16	4351.8551	233.8528

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	4359.1663	234.0492	77 in.	4656.6366	241.9032
9/16	4366.4835	234.2455	1/16	4664.1992	242.0995
5/8	4373.8067	234.4419	1/8	4671.7678	242.2959
11/16	4381.1361	234.6382	3/16	4679.3416	242.4922
3/4	4388.4715	234.8346	1/4	4686.9215	242.6886
13/16	4396.3132	235.0309	5/16	4694.5097	242.8849
7/8	4403.1610	235.2273	3/8	4702.1039	243.0813
15/16	4410.5150	235.4236	7/16	4709.7033	243.2776
			1/2	4717.3087	243.4740
75 in.	4417.8750	235.6200	9/16	4724.9204	243.6703
1/16	4425.2412	235.8163	5/8	4732.5381	243.8667
1/8	4432.6135	236.0127	11/16	4740.1620	244.0630
3/16	4439.9910	236.2090	3/4	4747.7920	244.2594
1/4	4447.3745	236.4054	13/16	4755.8782	244.4557
5/16	4454.7663	236.6017	7/8	4763.0705	244.6521
3/8	4462.1642	236.7981	15/16	4771.1690	244.8484
7/16	4469.5672	236.9944			
1/2	4476.9763	237.1908	78 in.	4778.3736	245.0448
9/16	4484.3916	237.3871	1/16	4786.0344	245.2411
5/8	4491.8130	237.5835	1/8	4793.7012	245.4375
11/16	4499.2406	237.7798	3/16	4801.3732	245.6338
3/4	4506.6742	237.9762	1/4	4809.0512	245.8302
13/16	4514.1141	238.1725	5/16	4817.1375	246.0265
7/8	4521.5600	238.3689	3/8	4824.4299	246.2229
15/16	4528.9622	238.5652	7/16	4832.1275	246.4192
			1/2	4839.8311	246.6156
76 in.	4536.4704	238.7616	9/16	4847.5409	246.8119
1/16	4543.9333	238.9579	5/8	4855.2568	247.0083
1/8	4551.4023	239.1543	11/16	4862.9789	247.2046
3/16	4558.8794	239.3506	3/4	4870.7071	247.4010
1/4	4566.3626	239.5470	13/16	4878.4415	247.5973
5/16	4573.8526	239.7433	7/8	4886.1820	247.7937
3/8	4581.3486	239.9397	15/16	4893.9287	247.9900
7/16	4588.8493	240.1360			
1/2	4596.3571	240.3324	79 in.	4901.6814	248.1864
9/16	4603.8706	240.5287	1/16	4909.4403	248.3827
5/8	4611.3902	240.7251	1/8	4917.2053	248.5791
11/16	4618.9159	240.9214	3/16	4924.9755	248.7754
3/4	4626.4477	241.1178	1/4	4932.7517	248.9718
13/16	4633.9858	241.3141	5/16	4940.5362	249.1681
7/8	4641.5299	241.5105	3/8	4948.3268	249.3645
15/16	4649.0802	241.7068	7/16	4956.1225	249.5608

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	4963.9243	249.7572	82 in.	5281.0296	257.6112
9/16	4971.7319	249.9535	1/16	5289.0781	257.8075
5/8	4979.5456	250.1499	1/8	5297.1426	258.0039
11/16	4987.3663	250.3462	3/16	5305.2073	258.2002
3/4	4995.1930	250.5426	1/4	5313.2780	258.3966
13/16	5003.0316	250.7389	5/16	5321.3570	258.5929
7/8	5010.8642	250.9353	3/8	5329.4421	258.7893
15/16	5018.7091	251.1316	7/16	5337.5324	258.9856
			1/2	5345.6287	259.1820
80 in.	5026.5600	251.3280	9/16	5353.7809	259.3783
1/16	5034.4171	251.5243	5/8	5361.8391	259.5747
1/8	5042.2803	251.7207	11/16	5369.9543	259.7710
3/16	5050.1486	251.9170	3/4	5378.0755	259.9674
1/4	5058.0230	252.1134	13/16	5386.2026	260.1637
5/16	5065.9027	252.3097	7/8	5394.3358	260.3601
3/8	5073.7944	252.5061	15/16	5402.4552	260.5564
7/16	5081.6883	252.7024			
1/2	5089.5883	252.8988	83 in.	5410.6206	260.7528
9/16	5097.4941	253.0951	1/16	5418.7722	260.9491
5/8	5105.4060	253.2915	1/8	5426.9299	261.1455
11/16	5113.8248	253.4878	3/16	5435.0928	261.3418
3/4	5121.2497	253.6842	1/4	5443.2617	261.5382
13/16	5129.1855	253.8805	5/16	5451.4389	261.7345
7/8	5137.1173	254.0769	3/8	5459.6222	261.9309
15/16	5145.0603	254.2732	7/16	5467.8106	262.1272
			1/2	5476.0051	262.3236
81 in.	5153.0094	254.4696	9/16	5484.2054	262.5199
1/16	5160.9647	254.6659	5/8	5492.4118	262.7163
1/8	5168.9260	254.8623	11/16	5500.6252	262.9126
3/16	5176.8925	255.0586	3/4	5508.8446	263.1090
1/4	5184.8651	255.2550	13/16	5517.0699	263.3053
5/16	5192.8460	255.4513	7/8	5525.3012	263.5017
3/8	5200.8329	255.6477	15/16	5533.5388	263.6980
7/16	5208.8250	255.8440			
1/2	5216.8231	256.0404	84 in.	5541.7824	263.8944
9/16	5224.8271	256.2367	1/16	5550.0322	264.0907
5/8	5232.8371	256.4331	1/8	5558.2881	264.2871
11/16	5240.8568	256.6294	3/16	5566.5491	264.4834
3/4	5248.8772	256.8258	1/4	5574.8162	264.6798
13/16	5256.9061	257.0221	5/16	5583.0916	264.8761
7/8	5264.9411	257.2105	3/8	5591.3730	265.0725
15/16	5272.9828	257.4148	7/16	5599.6596	265.2688

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	5607.9523	265.4652	87 in.	5944.6926	273.3192
9/16	5616.2508	265.6615	1/16	5953.2369	273.5155
5/8	5624.5554	265.8579	1/8	5961.7873	273.7119
11/16	5632.8662	266.0542	3/16	5970.3429	273.9082
3/4	5641.1845	266.2506	1/4	5978.9045	274.1046
13/16	5649.5071	266.4469	5/16	5987.4749	274.3009
7/8	5657.8357	266.6433	3/8	5996.0504	274.4973
15/16	5666.1723	266.8396	7/16	6004.6315	274.6936
			1/2	6013.2187	274.8900
85 in.	5674.5150	267.0360	9/16	6021.8117	275.0863
1/16	5682.8630	267.2323	5/8	6030.4108	275.2827
1/8	5691.2170	267.4287	11/16	6039.0169	275.4790
3/16	5699.5762	267.6250	3/4	6047.6290	275.6754
1/4	5707.9415	267.8214	13/16	6056.2470	275.8717
5/16	5716.3151	268.0177	7/8	6064.8710	276.0681
3/8	5724.6947	268.2141	15/16	6073.5013	276.2644
7/16	5733.0795	268.4104			
1/2	5741.4703	268.6068	88 in.	6082.1376	276.4608
9/16	5749.8670	268.8031	1/16	6090.7801	276.6671
5/8	5758.2697	268.9997	1/8	6099.4287	276.8535
11/16	5766.6794	269.1958	3/16	6108.0824	277.0498
3/4	5775.0952	269.3922	1/4	6116.7422	277.2462
13/16	5783.5168	269.5885	5/16	6125.4103	277.4425
7/8	5791.9445	269.7849	3/8	6134.0844	277.6389
15/16	5800.3784	269.9812	7/16	6144.2637	277.8352
			1/2	6151.4491	278.0316
86 in.	5808.8184	270.1776	9/16	6160.1403	278.2279
1/16	5817.2651	270.3739	5/8	6169.8376	278.4243
1/8	5825.7168	270.5703	11/16	6177.5418	278.6206
3/16	5834.1742	270.7666	3/4	6186.2521	278.8170
1/4	5842.6376	270.9630	13/16	6194.9683	279.0133
5/16	5851.1093	271.1593	7/8	6203.6905	279.2097
3/8	5859.5871	271.3557	15/16	6212.4189	279.4060
7/16	5868.0701	271.5520			
1/2	5876.5591	271.7484	89 in.	6221.1534	279.6024
9/16	5885.0540	271.9447	1/16	6229.8941	279.7987
5/8	5893.5549	272.1411	1/8	6238.6408	279.9951
11/16	5902.0620	272.3374	3/16	6247.3927	280.1914
3/4	5910.5767	272.5338	1/4	6256.1507	280.3878
13/16	5919.0965	272.7301	5/16	6264.9170	280.5841
7/8	5927.6224	272.9265	3/8	6273.6893	280.7805
15/16	5936.1545	273.1228	7/16	6282.4668	280.9768

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
$\frac{1}{2}$	6291.2503	281.1732	92 in.	6647.6258	289.0272
$\frac{9}{16}$	6300.0397	281.3695	$\frac{1}{16}$	6656.6609	289.2235
$\frac{5}{8}$	6308.8351	281.5659	$\frac{1}{8}$	6665.7021	289.4199
$\frac{11}{16}$	6317.6375	281.7622	$\frac{3}{16}$	6674.7485	289.6162
$\frac{3}{4}$	6326.4460	281.9586	$\frac{1}{4}$	6683.8010	289.8125
$\frac{13}{16}$	6335.2603	282.1549	$\frac{5}{16}$	6692.8618	290.0089
$\frac{7}{8}$	6344.0807	282.3513	$\frac{3}{8}$	6701.9286	290.2053
$\frac{15}{16}$	6352.9073	282.5476	$\frac{7}{16}$	6711.5001	290.4016
			$\frac{1}{2}$	6720.0787	290.5980
90 in.	6361.7400	282.7440	$\frac{9}{16}$	6729.6628	290.7943
$\frac{1}{16}$	6370.5789	282.9403	$\frac{5}{8}$	6738.2530	290.9907
$\frac{1}{8}$	6379.4238	283.1367	$\frac{11}{16}$	6747.3497	291.1870
$\frac{3}{16}$	6388.7739	283.3330	$\frac{3}{4}$	6756.4525	291.3834
$\frac{1}{4}$	6397.1300	283.5294	$\frac{13}{16}$	6765.5614	291.5797
$\frac{5}{16}$	6405.9944	283.7257	$\frac{7}{8}$	6774.6763	291.7761
$\frac{3}{8}$	6414.8649	283.9221	$\frac{15}{16}$	6783.7975	291.9724
$\frac{7}{16}$	6423.7906	284.1184			
$\frac{1}{2}$	6432.6223	284.3148	93 in.	6792.9248	292.1688
$\frac{9}{16}$	6441.5101	284.5111	$\frac{1}{16}$	6802.0581	292.3651
$\frac{5}{8}$	6450.4039	284.7075	$\frac{1}{8}$	6811.1974	292.5615
$\frac{11}{16}$	6459.3043	284.9038	$\frac{3}{16}$	6820.3420	292.7578
$\frac{3}{4}$	6468.2107	285.1002	$\frac{1}{4}$	6829.4927	292.9542
$\frac{13}{16}$	6477.1232	285.2965	$\frac{5}{16}$	6838.6517	293.1505
$\frac{7}{8}$	6486.0418	285.4929	$\frac{3}{8}$	6847.8167	293.3469
$\frac{15}{16}$	6494.9566	285.6892	$\frac{7}{16}$	6856.9869	293.5432
			$\frac{1}{2}$	6866.1631	293.7396
91 in.	6503.8974	285.8856	$\frac{9}{16}$	6875.3454	293.9359
$\frac{1}{16}$	6512.8344	286.0819	$\frac{5}{8}$	6884.5338	294.1323
$\frac{1}{8}$	6521.7775	286.2783	$\frac{11}{16}$	6893.7337	294.3286
$\frac{3}{16}$	6530.7258	286.4746	$\frac{3}{4}$	6902.9296	294.5250
$\frac{1}{4}$	6539.6801	286.6710	$\frac{13}{16}$	6912.1366	294.7213
$\frac{5}{16}$	6548.6427	286.8673	$\frac{7}{8}$	6921.3497	294.9177
$\frac{3}{8}$	6557.6114	287.0637	$\frac{15}{16}$	6930.5691	295.1140
$\frac{7}{16}$	6566.5857	287.2600			
$\frac{1}{2}$	6573.5651	287.4564	94 in.	6939.7946	295.3104
$\frac{9}{16}$	6584.5511	287.6527	$\frac{1}{16}$	6949.5261	295.5067
$\frac{5}{8}$	6593.5431	287.8491	$\frac{1}{8}$	6958.2636	295.7031
$\frac{11}{16}$	6602.5443	288.0454	$\frac{3}{16}$	6968.0064	295.8994
$\frac{3}{4}$	6611.5462	288.2418	$\frac{1}{4}$	6976.7552	296.0958
$\frac{13}{16}$	6620.5569	288.4381	$\frac{5}{16}$	6986.0123	296.2921
$\frac{7}{8}$	6629.5736	288.6345	$\frac{3}{8}$	6995.2755	296.4885
$\frac{15}{16}$	6638.5967	288.8388	$\frac{7}{16}$	7004.5439	296.6848

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
1/2	7013.8183	296.8812	97 in.	7389.8288	304.7352
9/16	7023.0988	297.0775	1/16	7399.3548	304.9315
5/8	7032.3853	297.2739	1/8	7408.8868	305.1279
11/16	7041.6784	297.4702	3/16	7418.6241	305.3242
3/4	7050.9775	297.6666	1/4	7427.9675	305.5206
13/16	7060.2827	297.8629	5/16	7437.5192	305.7169
7/8	7069.5940	298.0593	3/8	7447.0769	305.9133
15/16	7075.9116	298.2556	7/16	7456.6398	306.1096
			1/2	7466.2087	306.3060
95 in.	7088.2352	298.4520	9/16	7475.7837	306.5023
1/16	7097.5738	298.6483	5/8	7485.3648	306.6987
1/8	7106.9005	298.8447	11/16	7494.9524	306.8950
3/16	7116.7415	299.0400	3/4	7504.5460	307.0914
1/4	7125.5885	299.2374	13/16	7514.1457	307.2877
5/16	7134.9443	299.4337	7/8	7523.7515	307.4841
3/8	7144.3052	299.6301	15/16	7533.3636	307.6804
7/16	7153.6717	299.8264			
1/2	7163.0443	300.0228	98 in.	7542.9818	307.8768
9/16	7172.4230	300.2191	1/16	7552.6060	308.0731
5/8	7181.8077	300.4155	1/8	7562.2362	308.2695
11/16	7191.1989	300.6118	3/16	7575.8717	308.4658
3/4	7200.5962	300.8082	1/4	7581.5132	308.6622
13/16	7209.9096	301.0045	5/16	7591.1630	308.8585
7/8	7219.4090	301.2009	3/8	7600.8189	309.0549
15/16	7228.8248	301.3972	7/16	7610.4800	309.2512
			1/2	7620.1471	309.4476
96 in.	7238.2466	301.5936	9/16	7629.8203	309.6439
1/16	7247.6741	301.7899	5/8	7639.4995	309.8403
1/8	7257.1083	301.9863	11/16	7649.1853	310.0366
3/16	7266.5474	302.1826	3/4	7658.8771	310.2330
1/4	7275.9926	302.3790	13/16	7668.5750	310.4293
5/16	7285.4461	302.5753	7/8	7678.2790	310.6257
3/8	7294.9056	302.7717	15/16	7687.9893	310.8220
7/16	7304.3703	302.9680			
1/2	7313.8411	303.1644	99 in.	7697.7056	311.0184
9/16	7323.3179	303.3607	1/16	7707.4279	311.2147
5/8	7332.8008	303.5571	1/8	7717.1563	311.4111
11/16	7342.2902	303.7534	3/16	7726.8900	311.6074
3/4	7351.7857	303.9498	1/4	7736.6297	311.8038
13/16	7361.2873	304.1461	5/16	7746.3777	312.0001
7/8	7370.7949	304.3425	3/8	7756.1318	312.1965
15/16	7380.3088	304.5388	7/16	7765.8910	312.3928

DIAMETERS, AREAS, ETC.—*Continued.*

Dia.	Area.	Circum.	Dia.	Area.	Circum.
½	7775.6563	312.5892	½	8413.4008	325.1556
9/16	7785.4277	312.7855	¾	8454.0944	325,9410
5/8	7795.2051	312.9819			
11/16	7804.9890	313.0782	104 in.	8494.8864	326.7264
¾	7814.7790	313.3746	¼	8535.7760	327.5118
13/16	7824.5751	313.5709	½	8576.7640	328.2972
7/8	7834.3772	313.7673	¾	8617.8504	329.0826
15/16	7844.1856	313.9636			
			105 in.	8659.0348	329.8680
100 in.	7854.0000	314.1600	¼	8700.3176	330.6534
¼	7893.3190	314.9454	½	8741.6980	331.4388
½	7932.7360	315.7308	¾	8783.1772	332.2242
¾	7972.2120	316.5162			
			106 in.	8824.7544	333.0096
101 in.	8011.8652	317.3016	½	8908.2028	334.5804
¼	8051.5772	318.0870			
½	8091.3870	318.8724	107 in.	8992.0444	336.1512
¾	8131.2953	319.6578	½	9076.2784	337.7220
102 in.	8171.3016	320.4432	108 in.	9160.9056	339.2928
¼	8211.4060	321.2286	½	9245.9248	340.8636
½	8251.6084	322.0140			
¾	8291.8696	322.7994	109 in.	9331.3372	342.4344
			½	9417.1420	344.0052
103 in.	8332.3085	323.5848			
¼	8372.8056	324.3702	110 in.	9503.3400	345.5760

A Table of Diameters, Areas, and Circumferences of Circles, in Feet, from 1 to 50 Feet.

Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
1 ft.	.7854	3 1⅝	2	13.6353	13 1
1	.9217	3 4⅝	3	14.1862	13 4⅛
2	1.0690	3 8	4	14.7479	13 7¼
3	1.2271	3 11	5	15.3206	13 10½
4	1.3962	4 2⅛	6	15.9043	14 1⅝
5	1.5761	4 5⅜	7	16.4986	14 4⅝
6	1.7671	4 8½	8	17.1041	14 7⅞
7	1.9689	4 11⅝	9	17.7205	14 11
8	2.1816	5 2¾	10	18.3476	15 2⅛
9	2.4052	5 5⅞	11	18.9858	15 5¼
10	2.6398	5 9	5 ft.	19.6350	15 8½
11	2.8852	6 2¼	1	20.2947	15 11⅝
2 ft.	3.1416	6 3⅜	2	20.9656	16 2¾
1	3.4087	6 6½	3	21.6475	16 5¾
2	3.6869	6 9⅝	4	22.3400	16 9
3	3.9760	7 0¾	5	23.0437	17 0⅛
4	4.2760	7 3⅞	6	23.7583	17 3¼
5	4.5869	7 7	7	24.4835	17 6⅜
6	4.9087	7 10¼	8	25.2199	17 9⅝
7	5.2413	8 1⅜	9	25.9672	18 0¾
8	5.5850	8 4½	10	26.7251	18 3⅞
9	5.9395	8 7⅝	11	27.4943	18 7⅛
10	6.3049	8 10¾	6 ft.	28.2744	18 10⅛
11	6.6813	9 1⅞	1	29.0649	19 1¼
3 ft.	7.0686	9 5	2	29.8668	19 4⅜
1	7.4666	9 8¼	3	30.6796	19 7½
2	7.8757	9 11⅜	4	31.5029	19 10⅝
3	8.2957	10 2½	5	32.3376	20 1⅞
4	8.7265	10 5⅝	6	33.1831	20 4⅞
5	9.1683	10 8¾	7	34.0391	20 8⅛
6	9.6211	10 11⅞	8	34.9065	20 11½
7	10.0846	11 3	9	35.7847	21 2⅜
8	10.5591	11 6⅛	10	36.6735	21 5½
9	11.0446	11 9⅜	11	37.5736	21 8¾
10	11.5409	12 0½	7 ft.	38.4846	21 11⅞
11	12.0481	12 3⅝	1	39.4060	22 3
4 ft.	12.5664	12 6¾	2	40.3388	22 6⅛
1	13.0952	12 9⅞	3	41.2825	22 9¼

DIAMETERS, AREAS, ETC.—*Continued.*

Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Inches.	Area in Feet.	Circum. in Feet & Inches.
4	42.2367	23 0⅜	6	86.5903	32 11¾
5	43.2022	23 2⅛	7	87.9697	33 2⅞
6	44.1787	23 6¾	8	89.3608	33 6⅛
7	45.1656	23 11	9	90.7627	33 9¼
8	46.1638	24 1⅛	10	92.1749	34 0⅜
9	47.1730	24 4⅛	11	93.5986	34 3½
10	48.1926	24 7¼	11 ft.	95.0334	34 6⅝
11	49.2236	24 10⅜	1	96.4783	34 9¾
8 ft.	50.2656	25 1½	2	97.9347	35 0⅞
1	51.3178	25 4⅝	3	99.4021	35 4⅛
2	52.3816	25 7⅞	4	100.8797	35 7¼
3	53.4562	25 11	5	102.3689	35 10⅝
4	54.5412	26 2⅛	6	103.8691	36 1½
5	55.6377	26 5¼	7	105.3794	36 4½
6	56.7451	26 8⅜	8	106.9013	36 7¾
7	57.8628	26 11½	9	108.4342	36 10⅞
8	58.9920	27 2¾	10	109.9772	37 2¾
9	60.1321	27 5¾	11	111.5319	37 5¼
10	61.2826	27 9	12 ft.	113.0976	37 8⅜
11	62.4445	28 0⅛	1	114.6732	37 11½
9 ft.	63.6174	28 3¼	2	116.2607	38 2⅝
1	64.8006	28 6⅜	3	117.8590	38 5¾
2	65.9951	28 9½	4	119.4674	38 8⅞
3	67.2007	29 0⅝	5	121.0876	39 0
4	68.4166	29 3¾	6	122.7187	39 3¼
5	69.6440	29 7	7	124.3598	39 6⅜
6	70.8823	29 10⅛	8	126.0127	39 9½
7	72.1309	30 1¼	9	127.6765	40 0⅝
8	73.3910	30 4⅜	10	129.3504	40 3¾
9	74.6620	30 7½	11	131.0360	40 6⅞
10	75.9433	30 11⅝	13 ft.	132.7326	40 10
11	77.2362	31 1¾	1	134.4391	41 1⅛
10 ft.	78.5400	31 5	2	136.1574	41 4⅜
1	79.8540	31 8⅛	3	137.8867	41 7½
2	81.1795	31 11¼	4	139.6260	41 10⅝
3	82.5160	32 2⅜	5	141.3771	42 1⅝
4	83.8627	32 5½	6	143.1391	42 4⅞
5	85.2211	32 8⅝	7	144.9111	42 8

DIAMETERS, AREAS, ETC.—*Continued.*

Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
8	146.6949	42 11⅛	10	222.5510	52 10½
9	148.4896	43 2¼	11	224.7603	53 1⅝
10	150.2943	43 5½	17 ft.	226.9806	53 4⅞
11	152.1109	43 8⅝	1	229.2105	53 8
14 ft.	153.9384	43 11¾	2	231.4525	53 11⅛
1	155.7758	44 2⅞	3	233.7055	54 2⅛
2	157.6250	44 6	4	235.9682	54 5⅜
3	159.4852	44 9⅛	5	238.2430	54 8½
4	161.3553	45 0¼	6	240.5287	54 11⅝
5	163.2373	45 3½	7	242.8241	55 2⅞
6	165.1303	45 6⅝	8	245.1316	55 6
7	167.0331	45 9¾	9	247.4500	55 9⅛
8	168.9479	46 0⅞	10	249.7781	56 0¼
9	170.8735	46 4	11	252.1184	56 3⅜
10	172.8091	46 7⅛	18 ft.	254.4696	56 6½
11	174.7565	46 11¼	1	256.8303	56 9⅝
15 ft.	176.7150	47 1½	2	259.2033	57 0⅞
1	178.6832	47 4⅝	3	261.5872	57 4
2	180.6634	47 7¾	4	263.9807	57 7⅛
3	182.6545	47 10⅞	5	266.3864	57 10¼
4	184.6555	48 2½	6	268.8031	58 1⅜
5	186.6684	48 5⅛	7	271.2293	58 4½
6	188.6923	48 8¼	8	273.6678	58 7⅝
7	190.7260	48 11⅜	9	276.1171	58 10¾
8	192.7716	49 2⅝	10	278.5761	59 2
9	194.8282	49 5¾	11	281.0472	59 5⅛
10	196.8946	49 8⅞	19 ft.	283.5294	59 8¼
11	198.9730	50 0	1	286.0210	59 11½
16 ft.	201.0624	50 3⅛	2	288.5249	60 2½
1	203.1615	50 6¼	3	291.0397	60 5⅝
2	205.2726	50 9⅝	4	293.5641	60 8¾
3	207.3946	51 0½	5	296.1107	60 11⅞
4	209.5264	51 3¾	6	298.6483	61 3⅛
5	211.6703	51 6½	7	301.2054	61 6¼
6	213.8251	51 10	8	303.7747	61 9½
7	215.9896	52 1⅛	9	306.3550	62 0½
8	218.1662	52 4¼	10	308.9448	62 3⅝
9	220.3537	52 7⅜	11	311.5469	62 6¾

DIAMETERS, AREAS, ETC.—*Continued.*

Dia. in Feet & Inches.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
20 ft.	314.1600	62 $9\frac{7}{8}$	2	421.5192	72 $9\frac{3}{8}$
1	316.7824	63 $1\frac{1}{8}$	3	424.5577	73 $0\frac{1}{2}$
2	319.4173	63 $4\frac{1}{4}$	4	427.6055	73 $3\frac{5}{8}$
3	322.0630	63 $7\frac{3}{8}$	5	430.6658	73 $6\frac{3}{4}$
4	324.7182	63 $11\frac{1}{2}$	6	433.7371	73 $9\frac{7}{8}$
5	327.3858	64 $1\frac{5}{8}$	7	436.8175	74 1
6	330.0643	64 $4\frac{3}{4}$	8	439.9106	74 $4\frac{1}{8}$
7	332.7522	64 $7\frac{7}{8}$	9	443.0146	74 $7\frac{1}{4}$
8	335.4525	64 11	10	446.1278	74 $10\frac{5}{8}$
9	338.1637	65 $2\frac{1}{4}$	11	449.2536	75 $1\frac{5}{8}$
10	340.8844	65 $5\frac{3}{8}$	24 ft.	452.3904	75 $4\frac{3}{4}$
11	343.6174	65 $8\frac{1}{4}$	1	455.5362	75 $7\frac{7}{8}$
21 ft.	346.3614	65 $11\frac{5}{8}$	2	458.6948	75 11
1	349.1147	66 $2\frac{3}{4}$	3	461.8642	76 $2\frac{1}{8}$
2	351.8804	66 $5\frac{1}{8}$	4	465.0428	76 $5\frac{1}{4}$
3	354.6571	66 9	5	468.2341	76 $8\frac{1}{2}$
4	357.4432	67 $0\frac{1}{4}$	6	471.4363	76 $11\frac{5}{8}$
5	360.2417	67 $3\frac{3}{8}$	7	474.6476	77 $2\frac{3}{4}$
6	363.0511	67 $6\frac{1}{2}$	8	477.8716	77 $5\frac{7}{8}$
7	365.8698	67 $9\frac{3}{8}$	9	481.1065	77 9
8	368.7011	68 $0\frac{3}{4}$	10	484.3506	78 $0\frac{1}{8}$
9	371.5432	68 $3\frac{1}{8}$	11	487.6073	78 $3\frac{1}{4}$
10	374.3947	68 7	25 ft.	490.8750	78 $6\frac{3}{8}$
11	377.2587	68 $10\frac{1}{4}$	1	494.1516	78 $9\frac{1}{2}$
22 ft.	380.1336	69 $1\frac{3}{8}$	2	497.4411	79 $0\frac{3}{4}$
1	383.0177	69 $4\frac{1}{2}$	3	500.7415	79 $3\frac{7}{8}$
2	385.9144	69 $7\frac{5}{8}$	4	504.0510	79 $7\frac{1}{8}$
3	388.8220	69 $10\frac{3}{4}$	5	507.3732	79 $11\frac{1}{8}$
4	391.7389	70 $1\frac{7}{8}$	6	510.7063	80 $1\frac{1}{4}$
5	394.6683	70 5	7	514.0484	80 $4\frac{3}{8}$
6	397.6087	70 $8\frac{1}{4}$	8	517.4034	80 $7\frac{5}{8}$
7	400.5583	70 $11\frac{1}{8}$	9	520.7692	80 $10\frac{3}{4}$
8	403.5204	71 $2\frac{1}{2}$	10	524.1441	81 $1\frac{1}{8}$
9	406.4935	71 $5\frac{5}{8}$	11	527.5318	81 5
10	409.4759	71 $8\frac{3}{4}$	26 ft.	530.9304	81 $8\frac{1}{8}$
11	412.4707	71 $11\frac{7}{8}$	1	534.3379	81 $11\frac{1}{4}$
23 ft.	415.4766	72 3	2	537.7583	82 $2\frac{3}{8}$
1	418.4915	72 $6\frac{1}{8}$	3	541.1896	82 $5\frac{1}{4}$

DIAMETERS, AREAS, ETC.—*Continued.*

Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
4	544.6299	82 $8\frac{5}{8}$	6	683.4943	92 $8\frac{1}{8}$
5	548.0830	82 $11\frac{7}{8}$	7	687.3598	92 $11\frac{1}{8}$
6	551.5471	83 3	8	691.2385	93 $2\frac{3}{8}$
7	555.0201	83 $6\frac{1}{8}$	9	695.1280	93 $5\frac{1}{2}$
8	558.5059	83 $9\frac{1}{4}$	10	699.0263	93 $8\frac{5}{8}$
9	562.0027	84 $0\frac{3}{8}$	11	702.9377	93 $11\frac{7}{8}$
10	565.5084	84 $3\frac{1}{2}$	30 ft.	706.8600	94 $2\frac{7}{8}$
11	569.0270	84 $6\frac{5}{8}$	1	710.7909	94 6
27 ft.	572.5566	84 $9\frac{7}{8}$	2	714.7350	94 $9\frac{1}{4}$
1	576.0949	85 1	3	718.6900	95 $0\frac{3}{8}$
2	579.6463	85 $4\frac{1}{4}$	4	722.6537	95 $3\frac{1}{2}$
3	583.2085	85 $8\frac{1}{8}$	5	726.6305	95 $6\frac{5}{8}$
4	586.7796	85 $11\frac{3}{8}$	6	730.6183	95 $9\frac{3}{4}$
5	590.3637	86 $1\frac{1}{2}$	7	734.6147	96 $0\frac{7}{8}$
6	593.9587	86 $4\frac{5}{8}$	8	738.6242	96 4
7	597.5625	86 $7\frac{7}{8}$	9	742.6447	96 $7\frac{1}{4}$
8	601.1793	86 11	10	746.6738	96 $10\frac{3}{8}$
9	604.8070	87 $2\frac{1}{8}$	11	750.7161	97 $1\frac{1}{2}$
10	608.4436	87 $5\frac{1}{4}$	31 ft.	754.7694	97 $4\frac{5}{8}$
11	612.0931	87 $8\frac{3}{8}$	1	758.8311	97 $7\frac{3}{4}$
28 ft.	615.7536	87 $11\frac{1}{2}$	2	762.9062	97 $10\frac{7}{8}$
1	619.4228	88 $2\frac{5}{8}$	3	766.9921	98 2
2	623.1050	88 $5\frac{3}{4}$	4	771.0866	98 $5\frac{1}{8}$
3	626.7982	88 9	5	775.1944	98 $8\frac{3}{8}$
4	630.5002	89 $0\frac{1}{8}$	6	779.3131	98 $11\frac{1}{2}$
5	634.2152	89 $3\frac{1}{4}$	7	783.4403	99 $2\frac{5}{8}$
6	637.9411	89 $6\frac{3}{8}$	8	787.5808	99 $5\frac{3}{4}$
7	641.6758	89 $9\frac{1}{2}$	9	791.7322	99 $8\frac{7}{8}$
8	645.4235	90 $0\frac{5}{8}$	10	795.8922	100 0
9	649.1821	90 $3\frac{3}{4}$	11	800.0654	100 $3\frac{1}{8}$
10	652.9495	90 $6\frac{7}{8}$	32 ft.	804.2496	100 $6\frac{3}{8}$
11	656.7300	90 $11\frac{1}{8}$	1	808.4422	100 $9\frac{1}{2}$
29 ft.	660.5214	91 $1\frac{1}{4}$	2	812.6481	101 $0\frac{5}{8}$
1	664.3214	91 $4\frac{3}{8}$	3	816.8650	101 $3\frac{3}{4}$
2	668.1346	91 $7\frac{1}{2}$	4	821.0904	101 $6\frac{7}{8}$
3	671.9587	91 $10\frac{5}{8}$	5	825.3291	101 10
4	675.7915	92 $1\frac{3}{4}$	6	829.5787	102 $1\frac{1}{8}$
5	679.6375	92 $4\frac{7}{8}$	7	833.8368	102 $4\frac{3}{8}$

DIAMETERS, AREAS, ETC.—*Continued.*

Dia. in Feet & Inches.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
8	838.1082	102 7½	10	1008.4736	112 6⅞
9	842.3905	102 10⅝	11	1013.1705	112 10
10	846.6813	103 1¾	36 ft.	1017.8784	113 1⅛
11	850.9855	103 4⅞	1	1022.5944	113 4¼
33 ft.	855.3006	103 8	2	1027.3240	113 7⅜
1	859.6240	103 11⅛	3	1032.0646	113 10⅝
2	863.9609	104 2¼	4	1036.8134	114 1¾
3	868.3087	104 5⅜	5	1041.5758	114 4⅞
4	872.6649	104 8⅜	6	1046.3491	114 8
5	877.0346	104 11¾	7	1051.1306	114 11⅛
6	881.4151	105 2⅞	8	1055.9257	115 2¼
7	885.8040	105 6	9	1060.7317	115 5⅜
8	890.2064	105 9⅛	10	1065.5459	115 9¼
9	894.6196	106 0¼	11	1070.3738	115 11⅝
10	899.0413	106 3⅜	37 ft.	1075.2126	116 2⅞
11	903.4763	106 6⅜	1	1080.0594	116 6
34 ft.	907.9224	106 9¾	2	1084.9201	116 9⅛
1	912.3767	107 0⅞	3	1089.7915	117 0¼
2	916.8445	107 4	4	1094.6711	117 3½
3	921.3232	107 7⅛	5	1099.5644	117 6½
4	925.8103	107 10¼	6	1104.4687	117 9⅝
5	930.3108	108 1⅜	7	1109.3810	118 0¾
6	934.8223	108 4⅝	8	1114.3071	118 4
7	939.3421	108 7¾	9	1119.2440	118 7⅛
8	943.8753	108 10⅞	10	1124.1891	118 10¼
9	948.4195	109 2	11	1129.1478	119 1⅜
10	952.9720	109 5⅛	38 ft.	1134.1176	119 4½
11	957.5380	109 8¼	1	1139.0953	119 7⅝
35 ft.	962.1150	109 11⅜	2	1144.0868	119 10¾
1	966.7001	110 2⅜	3	1149.0892	120 2
2	971.2989	110 5¾	4	1154.0997	120 5⅛
3	975.9085	110 8⅞	5	1159.1239	120 8⅜
4	980.5264	111 0	6	1164.1591	120 11⅜
5	985.1579	111 3⅛	7	1169.2023	121 2½
6	989.8003	111 6¼	8	1174.2592	121 5⅝
7	994.4509	111 9⅜	9	1179.3271	121 8¾
8	999.1151	112 0½	10	1184.4030	121 11⅞
9	1003.7902	112 3¾	11	1189.4927	122 3⅛

Diameters, Areas, etc.—*Continued.*

Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
39 ft.	1194.5934	122 6¼	2	1396.4619	132 5⅝
1	1199.7195	122 9½	3	1401.9880	132 8¾
2	1204.8244	123 0½	4	1407.5219	132 11⅞
3	1209.9577	123 3⅝	5	1413.0698	133 3
4	1215.0990	123 6¾	6	1418.6287	133 6⅛
5	1220.2542	123 9⅞	7	1424.1952	133 9¼
6	1225.4203	124 1⅛	8	1429.7759	134 0½
7	1230.5943	124 4¼	9	1435.3675	134 3⅝
8	1235.7822	124 7⅜	10	1440.9668	134 6¾
9	1240.9810	124 10½	11	1446.5802	134 9⅞
10	1246.1878	125 1⅝	43 ft.	1452.2046	135 1
11	1251.4084	125 4¾	1	1457.8365	135 4⅛
40 ft.	1256.6400	125 7⅞	2	1463.4827	135 7¼
1	1261.8794	125 11	3	1469.1397	135 10½
2	1267.1327	126 2¼	4	1474.8044	136 1⅝
3	1272.3970	126 5⅜	5	1480.4833	136 4¾
4	1277.6692	126 8½	6	1486.1731	136 7⅞
5	1282.9553	126 11⅝	7	1491.8705	136 11
6	1288.2523	127 2¾	8	1497.5821	137 2⅛
7	1293.5572	127 5⅞	9	1503.3046	137 5¼
8	1298.8760	127 9	10	1509.0348	137 8⅜
9	1304.2057	128 0¼	11	1514.7791	137 11⅝
10	1309.5433	128 3⅜	44 ft.	1520.5344	138 2¾
11	1314.8949	128 6½	1	1526.2971	138 5⅞
41 ft.	1320.2574	128 9⅝	2	1532.0742	138 9
1	1325.6276	129 0¾	3	1537.8622	139 0⅛
2	1331.0119	129 3⅛	4	1543.6578	139 3¼
3	1336.4071	129 7	5	1549.4676	139 6⅜
4	1341.8101	129 10⅛	6	1555.2883	139 9⅝
5	1347.2271	130 1⅜	7	1561.1165	140 0¾
6	1352.6551	130 4½	8	1566.9591	140 3⅞
7	1358.0908	130 7⅝	9	1572.8125	140 7½
8	1363.5406	130 10¾	10	1578.6735	140 10⅛
9	1369.0012	131 1⅞	11	1584.5488	141 1¼
10	1374.4697	131 5	45 ft.	1590.4350	141 4⅜
11	1379.9521	131 8⅛	1	1596.3286	141 7½
42 ft.	1385.4456	131 11⅜	2	1602.2366	141 10¾
1	1390.2467	132 2½	3	1608.1555	142 1⅞

DIAMETERS, AREAS, ETC.—*Continued.*

Dia. in Feet & Inches.	Area in Feet.	Circum. in Feet & Inches.	Dia. in Feet & Ins.	Area in Feet.	Circum. in Feet & Inches.
4	1614.0819	142 5	9	1790.7610	150 0⅛
5	1620.0226	142 8⅛	10	1797.0145	150 3¼
6	1625.9743	142 11¼	11	1803.2826	150 6⅜
7	1631.9334	143 2⅜	48 ft.	1809.5616	150 9½
8	1637.9068	143 5½	1	1815.8477	151 0⅝
9	1643.8912	143 8¾	2	1822.1485	151 3¾
10	1649.8831	143 11⅞	3	1828.4602	151 6⅞
11	1655.8892	144 3	4	1834.7791	151 10⅛
46 ft.	1661.9064	144 6⅛	5	1841.1127	152 1¼
1	1667.9308	144 9¼	6	1847.4571	152 4⅜
2	1673.9698	145 0⅜	7	1853.8087	152 7½
3	1680.0196	145 3½	8	1860.1750	152 10⅝
4	1686.0769	145 6⅝	9	1866.5521	153 1¾
5	1692.1485	145 9⅞	10	1872.9365	153 4⅞
6	1698.2311	146 1⅛	11	1879.3355	153 8⅛
7	1704.3210	146 4⅛	49 ft.	1885.7454	153 11¼
8	1710.4254	146 7¼	1	1892.1724	154 2⅜
9	1716.5407	146 10⅜	2	1898.5041	154 5½
10	1722.6634	147 1½	3	1905.0367	154 8⅝
11	1728.8005	147 4⅝	4	1911.4965	154 11⅞
47 ft.	1734.9486	147 7¾	5	1917.9609	155 2⅞
1	1741.1039	147 11	6	1924.4263	155 6
2	1747.2738	148 2⅛	7	1930.9188	155 9¼
3	1753.4545	148 5¼	8	1937.3159	156 0⅛
4	1759.6426	148 8⅜	9	1943.9140	156 3½
5	1765.8452	148 11½	10	1950.4392	156 6⅝
6	1772.0587	149 2⅝	11	1956.9691	156 9¼
7	1778.2795	149 5⅞	50 ft.	1963.5000	157 0⅞
8	1784.5148	149 8⅛			

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